Notes on track

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NOTES ON TRACK.

CONSTRUCTION AND MAINTENANCE

BY

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them, principally because one not conversant with such books in their entire scope is liable to mistrust his ability to pick out those parts which he might comprehend. For the benefit of persons seeking familiarity with easement curves, some of the problems involved have been demonstrated, as in a text-book, one object in view being to show that the use of such curves, in all ordinary cases, is not so complicated with mathematics as some may have supposed.

A considerable volume of descriptive matter that is used largely in illustration of practice or of principles discussed has been arranged in the form of supplementary notes. While most of this matter is regarded as essential to a comprehensive treatment of the various subjects to which it relates, and therefore exceptional to the class of matter customarily reserved for use in an appended form, there were two reasons for the arrangement. In the first place, it serves the convenience of the general reader, who may wish to omit extended reference or numerous concrete applications; and, secondly, it gave opportunity to make use of a smaller size of type than seemed appropriate for the purpose of a general treatment, thereby effecting some economy in space. In this edition certain new devices and developments, brought out since the publication of the first edition, or within recent time, are considered in this supplementary chapter.

A constant aim has been to follow practice up to date, and give reference to all new improvements which seemed likely to assume future importance. One particular object in view has been to cover as widely as possible the development of labor-saving machinery. In this line there has been much improvement within the past few years, and this phase of the subject is destined to be one of increasing interest.

I shall appreciate the kindness of any reader who will notify me of typographical or other imperfections discovered, or who will give me the benefit of his criticism upon any statement or matter of opinion in which he may find interest, or send me data or records of work to compare with similar data herein contained. Having treated of many questions on which there are conflicting opinions among expert trackmen and engineers, I could not resist the temptation to now and then venture my own opinion on such matters. I am very sure, therefore, that certain opinions herein expressed are contrary to the views of some maintenance-of-way men. To a very large extent, however, I have accorded questions of this character full discussion, presenting the views of both sides, believing that those interested in a work of this kind would appreciate the enumeration of established opinions fully as well as, and perhaps better than, the conclusions which any one person may have drawn from the same. It is needless to here dwell upon the advantages of discussion, for much benefit is sometimes derived in the way of suggestion, even though the result may fall short of definite conclusions. In this light it is sometimes profitable to launch an opinion, notwithstanding that opposition to the same can readily be anticipated. A writer on track who would confine his remarks to matters of settled opinion would necessarily have to omit many interesting features of practice.

W. M. Camp.

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CHAPTER I.

TRACK FOUNDATION.

1. **Introduction.**—The proper construction of railroad track and the efficient and economical maintenance of the same involve the science of engineering. There are so many definitions of the term "engineering" that a new one will not be attempted here, for almost any of them apply. One which fits the case very well may be comprehended by saying that to properly construct or maintain track is to know how to "make a dollar go the farthest." Of the three recognized stages having to do with track in service, either construction or maintenance is a field of engineering of no less importance than that of track location. Considering the specializing tendency of the times, which has created such professions as bridge engineering, hydraulic engineering, sanitary engineering, and other departments included within the scope of civil engineering, why should there not be recognized a distinct class of work known as "track engineering?" Track and roadbed represent a much larger investment than do bridges, waterworks, or sewers, or more than all combined, and the problems which have to be studied and solved in relation to track are about as difficult as one will find in any line of engineering work.

Track engineering begins with the reconnoissance or preliminary surveying and must be followed through the location and the construction of the roadbed, the building of the track proper, and continue with the maintenance and repairs ever afterward; for in no sense can it be excluded during the progress of any of these steps. In locating the line for a railroad track, it may often happen that a choice may be had between soils or substrata of different kinds, without sacrificing anything in matters pertaining to right of way, grades or curvature; or the local conditions peculiar to one side of a valley may differ so widely from those of the opposite side, in such respects, for instance, as exposure to wind and drifting snow, slides, falling rocks, surface drainage, springs of water, stream encroachments on the roadbed, the shading of the right of way by steep hills or by forest, as to materially affect the cost of maintenance. Although the relation of such matters to the work and expense of track maintenace is apparent yet it has not always been considered during that part of the work so often regarded as preliminary in a too strict sense. If things are allowed to shift too much for themselves during construction it will usually be found that methods of work will be permitted which will result in inferior service. In these days when so much of industry is dependent upon the activities of corporations, and when labor is becoming more and more divided, men in general will take less and less interest in that which they engage to do, except in what may appear to promise them more or less direct returns in higher compensation or in reputation. Obviously, then, there will be a larger demand for men whose occupation it shall be to maintain a close watch on details, with a view to turn aside all the undirected and misdirected tendencies which might lead to extravagance, inefficiency, or whatever in the end might operate depressingly upon dividends, which constitute the ultimate aim of the projectors of railroads.

Now, it does not matter by what name we choose to call this occupation—whether it be intelligent foremanship, good railroading or engineering—there is room for it; but if any system of work or management which can be applied to track supervision in a manner to make track more durable, safer, or less expensive to maintain, be not engineering, then I know of no appropriate term to apply to it. In almost all industrial lines, particularly those identified with mechanical or electrical engineering, it is the chief consideration of the science that questions of economy in maintenance or running expenses shall not only share equally with the attention usually given by the engineer to construction in general, but that they must be entertained by him particularly and studiously in coexistence with his plans of construction. Already a great deal more study is being devoted to track engineering than was the case when 60-ton locomotives and 20-ton freight cars were typical of rolling stock, and the tendencies indicate a still larger application of engineering principles to this line of work.

It is not difficult to explain the situation in the past. Track is so extended over distance, when compared with other works or structures; the roadbed, the ballast and the materials of which the track is constructed are subject to such inequalities and irregularities; the track structure is so simple and deteriorates by such insensible degrees; and the wide-spread but mistaken idea that "main strength and awkwardness" are as efficient in its service as intelligence and skill, has so prevailed, that, in the very nature of things, the officials not directly responsible for the condition of the track were slow to grasp the idea that track should be studied as thoroughly as other engineering structures. The simplicity of the track structure is the deceptive element in questions relating to maintenance economy, for ideas concerning the stability of track are too frequently confined merely to the question of approved qualities of rails, ties and ballast. The fact that the track structure lies upon the surface, exposed to the extreme action of the natural elements, is a very important consideration in track engineering.

One of the most expedient resources available for moving people out of a rut is to make them feel the disadvantages of their position from a financial point of view. Opportunities for applying this principle to railroad track are easy to find. For the sake of illustration, let us for a moment contrast the track with some other engineering structure in use on railroads—say an iron or steel bridge. Now the average bridge is considered a costly structure, and much care is taken with every detail which goes into its make-up. The foundation upon which it rests is usually built to stand; all materials going into it are of the most substantial quality; all the pieces going into the superstructure are not only carefully made and inspected but are carefully handled when being put together; connections or joints between pieces are made stronger than the pieces themselves; every piece in the whole system is carefully adjusted to its place, so as to bear its proper stress, and that before any load is allowed to come upon the bridge. The structure is supposed to be kept well painted; it is watched and inspected frequently; and should there be found deflections much exceeding those calculated upon, or any behavior tending to show the least weakness, the whole thing is counted a failure. Such is engineering, and such is what makes weak railroad bridges scarce and bridge accidents of seldom occurrence. All the care exercised costs, but everybody knows that it is money saved and that it is good economy. As for the track, who does not know that ten miles of average track costs more than the average bridge of several hundred feet length, foundation and all? Yet who does not know that when put together the work has too frequently been done with a rush and that reckless work due to this cause has been too frequently overlooked? In how many instances has one not seen the work improperly finished, as, for instance, when ditching and such necessary work was left to be completed at a time when its cost must necessarily amount to much more than what it would have been in the first place? How many have been the cases where costly materials are worn out or rendered useless through lack of attention, or through ignorant supervision, long before they should be? Now all this costs money and it is known to be false economy, yet it has not been so generally conceded as have like mistakes in some other lines of engineering. What then is needed? I maintain that the same strict and intelligent engineering is needed that is usually applied to some other railway affairs.

It is supposed by not a few trackmen that the term "engineering" relates to matters in which they are not concerned; while on the other hand, to some railroad surveyor or draftsman the employment of the word in connection with trackmen's work is to disparage his occupation and its relative importance to the occupation of a trackman. Where such is the presumption both parties have a mistaken conception of the word engineering. I consider that there are many roadmasters and section foremen who have more to do with track engineering than some men commonly known as civil engineers, yet whose experience has been nothing more than surveying or drafting, no matter how extended their experience within such limits may have been. Really, surveying and mathematical calculations cut but a small figure in track maintenance. It is true that in some respects track location can be fairly well learned from books, drawings and office work, but how to build and maintain track to best meet diverse conditions cannot be learned between covers or in an office. The experience necessary to teach such knowledge must be had by actual contact with the work. According to some men's ideas track engineering is largely a matter of surveying and the ability to select good materials, but in the following pages it is attempted to show that it also requires intelligent manipulation and an adjustment of parts involving no mean order of skilled labor.

There can be no question but that some prestige is lost to the engineering profession from the fact that so many men who have a general knowledge of engineering principles attempt to make their applications too specific, without having acquired that view of things which comes only by patient and earnest devotion to the particular line of duty, with some responsibility therein; and so it is with track engineering. There are men who have never so much as sweat a drop in any kind of service calculated to impart a knowledge of track work, or lost a moment's sleep caring for the safety of track, who, nevertheless, are ever eager to propose what they think to be some track improvement; and as a rule their ideas on improvements amount to about as much as their services have. And so, many practical railway men who, in reality, do most of the thinking and perform most of the work that is worthy to be called engineering, hold in a sort of contempt the very term which best describes the results of their own efforts. Between these two classes there has existed to no small extent an attitude which has tended to discourage practical men in what they ought to seek after more than they do; and as a partial result of this there is, at least, a misconception of terms.

Almost everywhere one hears it said: "Theory is not practice," "Theory will not work in practice," etc. The term theory is too often used with that looseness of expression synonymous with inference, guesswork, speculation, etc.; whereas in its proper sense it applies only to those ideas which have not been known to fail under any reasonable test, and for which there are, therefore, good grounds for putting them to further test wherever they can reasonably be applied. Again, what would be theory in a sense pure and simple might not be theory as applicable to every case where one might wish to make it hold; example: One may find tables giving the outside rail on curves as much as 14 ins. elevation, for a certain degree of curve and a certain speed not uncommonly made. Now, as for some specially built vehicle running upon some specially built track, this application may be theory; but it is not theory which has to do with the conditions which obtain in railroading; when applied to such it is not theory but nonsense, because no account is taken of circumstances which might be known. Some man's ideas about the application of some mathematical formula or scientific principle does not necessarily constitute a theory.

The fact of the matter is that all competent men, commonly called "practical" men, use more theory than they may think they do; it guides them in much or all of their work, although they may never have thought to express it in so many words, perhaps. What men need to have in order to accomplish the highest results in any line of work is a clear understanding of the principles they are using. And then, too, unless men understand such principles, or the theory of their own work, they are unable to apply themselves to such changing conditions as may arise in any business experience of a few years. Practice without some knowledge of the principles involved is like working blindfolded, while, on the other hand, a knowledge of principles without some practical ideas of applying them is useless. And then, in order to get a proper conception of the principles underlying a case it is essential that right premises be taken. Theory cannot be formed upon faulty observation, neither is it derived by defective reasoning, nor does it necessarily follow from hit or miss speculations. Correct theory (meaning theory correctly applied) and good practice are always in strict accord; and where they apparently are not, an investigation will always lead to some interesting disclosure; generally showing that there was either a misconception of principles or an attempt to make a wrong application of them. Or, in every case where an idea is said to work well in practice it is needless to say that it conforms to principle; and if seemingly not, then the legitimate principles involved are not well understood. The only essential difference between correct theory and good practice, in one way of expressing it, is that practice so called, must employ a knowledge of details, while theory, in distinction therefrom, may stand entirely upon a knowledge of principles—which, of course, must be learned from details, although not necessarily from the details of the thing or practice to which the application is made. Hence it is that a knowledge of principles, as applying to some particular practice, sometimes precedes a knowledge of its details and sometimes vice versa. Good practice is theory rightly applied; or theory may be called the explanation of, or the reason for, the practice. They both represent truth, when rightly comprehended; and how to comprehend the two in their right relations and to carry them out in application is engineering.

2. Meaning of Terms.—A railroad is made up essentially of three parts: the foundation, the ballast and the track. The foundation is the earth support, the upper surface of which is usually brought to an established line known as sub-grade. In the case of an embankment or a fill the foundation is the earthwork; in a cut it is the lower limit of the earthwork. Ballast may be considered to be some kind of material placed upon the foundation to put track in surface and afford drainage, and perhaps also to hold the track in alignment. In the case of dirt or "mud" ballast the foundation might be considered as extending to the track, the ballast being in that case only that portion of the material which lies between the ties; and the drainage, so far as accomplished, taking place on the surface. The track is the rails, with their fastenings, and the ties. While, as regards only the path of the wheels, the rails alone might be considered as constituting the track, the fact that the tie serves as a means of holding the rails to proper gage, as well as serving for a support, and that the whole is a separate, distinct structure, would make it seem that the tie ought to be considered an integral part of the track. For purposes of general description it is also more convenient not to subdivide the portions of the road further.

As names for these parts several terms have grown out of practice, some of which do not express the real meaning, and as a result there is more or less interchange in their application, and, consequent confusion. For instance, the term "grade" is in common usage among contractors and track-layers to denote the upper surface of the foundation, when, as all know, the same term is the universally accepted expression for rate of ascent or descent with respect to level. The term "roadbed" is sometimes used to denote the foundation, sometimes the ballast, and sometimes the surface of contact of the ballast with the ties; that is, in the last case it is used in the same sense as when the bottom of a river is spoken of as its "bed." The term "track" is sometimes used to denote both the superstructure and the ballast. In imitation of the English, some members of the engineering profession choose to call the combined track, ballast and foundation "the permanent way," which, by the way, is something of a misnomer. There is nothing about American railroad track that is particularly permanent, except, perhaps, the line establishing the location; but to maintain the track to this requires constant or continued labor; while the materials in track and ballast (and foundation, too, sometimes) require, in course of time, more or less frequently, either changing or replenishing. Even stone arch bridges, on some of our roads, have failed after less than fifty years of service.

In the present connection it is instructive to enquire into the significance of the term "permanent way" as it is used in England. In that country the application of the term arises from the manner in which track is constructed. After the roadbed is completed a stretch of "temporary" track is laid with old materials, and after the ballast is hauled in this track is lifted approximately to the final grade and ballasted. The ballast is then leveled to the bottoms of the ties, the new rails and ties are strung out along each side of the track, the temporary track torn up, the ballast dressed off to a smooth surface, the new or "permanent" track is laid and thoroughly tamped and the ballast filled in and dressed off to standard section. Thus the road is extended by first laying temporary track, a section at a time, and repeating the process just described, using the old materials over and over. By such practice the lifting of new track through any considerable hight is avoided and trains are not permitted to run upon the same until it is put into final condition. The term "permanent way" is thus used in a comparative sense, to distinguish the road, as completed for traffic, from the temporary track laid down for the purpose of forwarding materials and placing the ballast. As applied to American roads, however, the term loses its English significance, for we do not build track in the manner described. As the term is also without application in a literal sense it is both un-American and in bad taste to speak of American railroad track as "permanent way."

In view of possible misunderstanding, some of the terms used in this book are here defined as follows: Track foundation is called the roadbed, and its upper surface, sub-grade. The material between the ties, and between the ties and the sub-grade line constitutes the ballast. The rails and ties, when united, are called track. The combination of these three parts, the roadbed, the ballast and the track, is known as a railroad or railway; or, simply, the road. The term "rail," or "the rail," is sometimes used to denote a piece of rail of standard length, say 30 ft., and sometimes to denote all such pieces on one side of the track taken collectively, the same as though the rails were jointless. The term "steel" and "the steel" have the same significance. A "piece of rail" refers to a piece shorter than standard length, or shorter than 30 ft. Maintenance of way is commonly understood to mean or include the maintenance of all the fixed property of a railroad, as track, bridges, buildings, signals and water supply. Where nothing is said to the contrary, the gage of all track herein considered is understood to be standard, or 4 ft. 8½ ins. The word "ton" without qualification means the American ton of 2000 lbs. Wherever locomotive weights are referred to the weight of the tender is not included. The term "ends of the ties" is commonly used to refer to that part of the ties which extends outside the rails.

3. The Roadbed.—It is not the purpose to deal here with those problems of locating the roadbed which belong properly to surveying, treatment of which can be found in the many books on field engineering. Neither can there be included the discussion of a subject of such scope as the more intricate engineering problem known as the economic theory of roadbed location, where the topography of the country gives rise to such questions as compensation between distance, grades and curvature. The object is to take up only those features of the roadbed which may in some way affect the condition of the track built upon it, either during the construction of the track or after it is put to its use.

Unlike almost all other foundations prepared to sustain a great weight, the roadbed of railroad track is largely of an unstable nature. Instead of seeking for a solid substratum, as is done when laying the walls of a building or when constructing a pier or abutment for a bridge, it is found expedient to take the surface of the ground pretty much as it is and, in excavation, go only so far as a predetermined grade line has been established, without reference to the nature or depth of the yielding soil; while, when this same established grade line lies above the ground there is added to the top surface such material of the same yielding nature as lies most conveniently for movement. Such, at its best, is the roadbed. This, with a comparatively thin layer of ballast material of such quality as the available expenditure will admit of (and, often, no better than common soil itself), must not only bear up a ponderous load, but bear it intermittently, and under conditions which increase the effects to a degree not possible with the same burden imposed as a stationary object. How, then, to construct, with such material, a formation extending over long distances, in a manner to endure not only the weight above but also the natural forces expending themselves around it, is the work of building a roadbed.

Roadbed Cross Sections.—Almost every railway has a standard cross section for roadbed, at least on paper, and among different roads these so-called "standards" vary considerably in form and in dimensions. So far as fills are concerned the width of the roadbed at sub-grade should afford at least a sufficient base for the ballast. Taking the depth of the ballast not to exceed 8 ins. below the bottoms of the ties, and allowing for a narrow shoulder of ballast against the ends of the ties, the ballast will overspread a strip of roadway about 14 ft. wide. The least permissible width for single-track roadbed at sub-grade is then about 14 ft., after shrinkage; and since the top width of an embankment should increase with hight it might be well to settle upon 16 ft., after shrinkage, as the least permissible width of roadbed at sub-grade on embankments exceeding, say, 10 ft. in hight. A width of 14 ft. allows for no shoulder on the roadbed outside the ballast; and although good track can be maintained upon roadbed without such shoulders, the conditions are by no means ideal, and the highest efficiency of support cannot be looked for on these dimensions. As for economy of maintenance, however, that is a matter having to do with the amount of surface repairs, which, of course, depend mostly upon the volume of the traffic. The situation with many railroads in this country is such that it would hardly be found economical to adopt such dimensions for roadbed as might, from the standpoint of efficiency alone, measure closely up to the ideal. For roads having but few trains daily it is a question whether the minimum widths of roadbed here given may be exceeded with any economy. On roads carrying heavy traffic 18 ft. is usually considered the least advisable width of roadbed for fills, and a maintained width of 20 ft. is sometimes found to be standard. On the Southern Ry. the standard permanent width of single-track roadbed on embankments, at sub-grade, is 14 ft.; on the Great Northern Ry. it is 14 ft. on tangents and 16 ft. on curves; on the Southern Pacific (existing high embankments) and Atchison, Topeka & Santa Fe (branch lines) roads, it is 15 ft.; on the Atchison, Topeka & Santa Fe (main line), Baltimore & Ohio, New York Central & Hudson River, Northern Pacific, Southern Pacific (for construction of new lines) and Louisville & Nashville roads it is 16 ft.; on the Chicago, Burlington & Quincy Ry. it is 17 ft.; on the Burlington, Cedar Rapids & Northern and Cincinnati, New Orleans & Texas Pacific roads it is 18 ft.; on the Philadelphia & Reading Ry. it is 18½ ft.; on the Pennsylvania R. R. it is 19 ft. 2 ins.; on the Illinois Central and Union Pacific roads it is 20 ft.; while on some cheaply built roads it is only 12 ft. The width of roadbed for double track exceeds the width for single track by the distance between track centers. Since in excavations the roadbed must be made wide enough to afford room for proper drainage parallel with the track, the width of roadbed in cuts is considered in connection with the subject of ditches.

The advantage of increasing the width of roadbed with depth of fill is that after the embankment has settled it can be built up to grade again by dumping material on top without having to replenish the slopes in order to get the necessary width of base. This principle of construction is adhered to on a number of roads. On the Chicago, Milwaukee & St. Paul Ry. the standard maintained width of roadbed, at sub-grade, on embankments is 18 ft., but on branch lines, a narrower roadbed has sometimes been constructed. In construction of new lines, however, it is the practice of this company to increase the width of roadbed at sub-grade 2 ft. for each 10 ft. in hight of the embankment. On the Michigan Central R. R. the roadbed is made 1 ft. wider for each 5 ft. increase in hight of embankment. The standard width of embankments on the Kansas City, Pittsburg & Gulf R. R. is 16 ft. for fills up to 15 ft. in hight and 18 ft. for embankments higher than 15 ft.

It is poor economy to make a fill so narrow that it must be widened while the work of ballasting is in progress, in order to keep the ends of the ties from overhanging the ballast, which has slidden down the bank. It is poor economy for two reasons: first, ballast, be it gravel or other material, is rather too expensive to use for widening embankments, if it must be hauled some distance; and secondly, gravel deposited upon a hard slope will slide off. The slope of an embankment cannot therefore be maintained in a manner to sustain the weight above, by depositing loose gravel upon a firmer substratum, without using a quantity of it which is entirely out of proportion to the quantity of filling required. Trackmen can recall the familiar spectacle of having seen half the ballast, which had been hauled for the purpose of ballasting and surfacing the track, lying either at the foot of the embankment slope or along its sides, to be crowded farther down by every workman stepping out of the way of a passing train, thus weakening the support which the ends of the ties ought to have. Insufficient support for the retention of the ballast is the most frequent cause of center-bound track. The first cost of extra material required to make the fill of proper width at sub-grade, which such materials as will lie stably along the slope, is small in comparison with the cost of afterwards wasting a large amount of more costly material which is not so well suited for the purpose of an embankment.

The roadbed should be brought to full width and completed before track-laying begins. Cuts and fills are often left to be widened after the track is laid, but it is nearly always one of those mistakes which cost. Engineers usually aim to have the cuttings make the fills, without hauling farther than can be done to advantage with teams. But in rare instances, where fills cannot be finished out from borrow pits, and material must be hauled a long distance, it is advisable sometimes to leave the widening of a cut, now and then, to be done with the work train rather than to waste it at the first. In such cases, however, it should be done as soon as a work train can be put on after the track is laid. Where some exceptional case of this kind is calculated upon and the practice does not become general for the whole line, there may be found a saving; but in the main, where the road is rushed through with earthwork only partly completed there usually follows much waste of ballast, which is lost by sliding off the narrow shoulder, and the track is flooded in cuts for want of proper ditches. In attempting to widen an old embankment having hard slopes, stones and lumps dumped from the top will roll to the bottom and out of the fill; and, when lying upon a harder surface, the quantity of material of any kind which must be used is disproportionate to the quantity which would be needed, during construction, just as in the case with gravel, above explained, because the weight from above will push the bottom of the slope out and the earth will not then stand at the same slope as when the fill is made with loose material all at one time. Work trains being always more or less hindered in their work by regular trains, it is well to do all that can be done on the roadbed before the track is laid, for it is nearly always the cheapest, the most economical, and by far the best plan. Where an embankment is deficient in width it is hardly worth while to raise the track to grade in ballasting, because track boosted upon a narrow heap of material obtained by robbing the side slopes will quickly settle, from want of lateral support to retain the ballast. It is just as well, and indeed better, in such cases, to permit the track to remain at such hight as is consistent with the width of the supporting base, even though there may be local depressions below the established grade line. In widening out an embankment on which ballast has already been deposited, the material added to extend the shoulders, unless it be the same material as the ballast itself, should never be built up higher than the bottom of the ballast, as to do so will obstruct the drainage.

For drainage purposes the roadbed ought to be somewhat higher in the middle than at the sides. Unless such is the case the water which settles through the ballast will find its way into the roadbed, soften the material and cause it to settle under the pressure of the traffic and heave during freezing weather. On standard cross sections it is customary to show the roadbed crowned 3 to 6 ins. in the middle, but the scheme is seldom carried into practice. Such negligence is one of the worst mistakes that is made in railroad construction. In cuttings it is an easy matter to crown the roadbed at the center, without extra expense, and on the natural earth the material is usually firm enough to preserve the sloped surfaces permanently. On embankments filled from trestles and in filling up ravines by dumping over the slopes it is impracticable to do this, but in filling an embankment by working from the bottom with teams the material can be so placed that the top of the roadbed will shed water fairly well. The standard roadbed of the Missouri, Kansas & Texas Ry., which is 16 ft. wide on embankments and 18 ft. wide in cuts, is flat for a distance of 4 ft. each side of the center line—that is, over a width corresponding to the length of the ties—but from a line directly under the ends of the ties there is a slope of 6 to 1 out over the shoulder. On curves the surface of the roadbed may be made flat and inclined to the same slant as that to which the track is to be elevated. This arrangement allows of an equal depth of ballast under both sides of the track and, therefore, an equal settlement for both sides, because all kinds of ballast in new track will settle some. It also effects an economy in the use of ballast. Roadbed which is not made to slope in this manner on curves should be widened on the outer side of the curve to provide the extra width of shoulder required for the higher and longer slope of the ballast on that side. Such extra width is especially needed where the roadbed is narrow or of minimum allowable width.

Grading.—The manner in which a fill is made has much to do with the efficiency with which it will support the track. The most solidly compacted work is had when horses are driven continually over the fill during the progress of its construction, as when hauling in carts, wagons or scrapers. Earthwork constructed by such means will usually settle but very little afterward. Shrinkage is greatest on embankments formed by dumpings from wheelbarrows, by machine graders or by casting the material by hand from side ditches. The method of depositing the material in roadbed construction, affecting so largely as it does the question of shrinkage, is a matter of no small importance; for when a fill settles, the track must be put again to surface with ballast. By providing against future settlement as far as possible there is curtailed an item of considerable expense. In the present connection, therefore, it may not be amiss to consider briefly some of the methods and means employed in roadbed construction.

Wheelbarrows and plank runways are used where the material to be moved must be taken across a ravine, or across a track, as at a side-hill cut in filling for a second track; or in moving material from borrow pits across ground that is too rough for team work; or in short hauls where the material is broken rock or is too largely intermixed with large stones or boulders, or where the ground is too thickly set with stumps to be easily taken up with plow and scrapers. Speaking generally of team work, drag scrapers or slips are considered the best vehicles for hauls up to about 90 ft.; wheel scrapers for hauls between 90 and 300 ft. in length; and dump carts or dump wagons where the material is to be moved more than 300 ft. The capacity of drag scrapers is 4½ to 5½ cu. ft., and on a short haul, like 25 or 30 ft., a team will move in one day about 70 cu. yds. of earth or other material that can be loosened up with a plow and readily picked up by the scraper. On a haul of 90 ft., a team and drag scraper will move about 50 cu. yds. in a day, and on a haul of 125 ft. about 40 cu. yds. The capacity of wheel scrapers is 9 to 12 cu. ft., where an extra team is not required for filling, and 12 to 16 cu. ft. where an extra or "snatch" team is generally used in filling. In ordinary material and under ordinary conditions a team and wheel scraper will move 50 to 55 cu. yds. of earth per day, on a haul of 90 ft.; about 40 cu. yds. on a haul of 300 ft., and about 30 cu. yds. on a haul of 450 to 500 ft. On the longer hauls, it pays, of course, to use the large-size scrapers. The capacity of a two-wheel cart hauled by one horse is ¼ to ⅓ cu. yd., according to the character of the roadway, and this vehicle is economical on hauls up to 1500 or 1800 ft. The capacity of four-wheel wagons hauled by two horses is generally about 1 cu. yd. and these are generally economical on hauls up to about 3500 ft. Where a large quantity of material is moved into one embankment a temporary track and dump cars is a very common arrangement. Over moderate distances the dump cars can be hauled to advantage with horses, but for distances exceeding 2000 ft. a small locomotive is generally more speedy and economical. Where the fill is to be made from a temporary trestle the use of dump cars is necessary. They are also generally used where the excavation is made with a steam shovel, although teams and wagons are occasionally employed in hauling from a steam shovel.

In districts where the ground can be plowed and the surface is not badly broken up grading machines are much used in railroad earthwork. The New Era grader consists of a strong vehicular frame mounted upon low wheels with wide tires. Suspended from the frame and connected to the front axle is a plow, with hand wheel and chains for regulating the depth of furrow. Running from the moldboard of the plow there is a side belt conveyor which moves at right angles with the course of the machine. The hight of delivery from this conveyor is regulated by hand wheel and chains, and the conveyor may be extended in sections to deliver the material as far as 22 ft. from the plow. The machine is drawn by eight or twelve horses hitched four abreast, or by a traction engine. On prairies, or on comparatively even ground, embankments 4 ft. high and full width for single track may be built up from the sides by deposits direct from the machine, or the machine may deliver into wagons driven alongside, as in making fills from cuts or wherever it is desired to deposit the material beyond the reach of the conveyor. A driver and two attendants are required for the operation of the machine and it is said that under favorable conditions 1000 to 1500 cu. yds. of earth can be handled in 10 hours. The handling of filling material with trains is treated at length in Chapter X, §148.

The amount of shrinkage or settlement of embankments, in hight, after completion depends upon the character of the material, the method of placing it and the weather conditions during construction. Embankments made of rock either loosely thrown down or deposited in any other way consolidate rapidly and do not shrink appreciably after completion. Among earth materials sand and gravel shrink least of all, and next in order come clay, loam and loose vegetable mould or surface soil, the last named shrinking or settling the most. As for methods of handling, the results are about in the following order: Embankments built with (1) drag scrapers are tramped most thoroughly by the teams and settle the least; and next in order come (2) wheel scrapers and carts; (3) wagons, when the material is deposited in horizontal layers; (4) cars unloaded from trestles; (5) carts, wagons or cars dumped over the side or end of the embankment; and (6) wheelbarrows and hand casting with shovels. The condition of the material when it is put into the embankment may depend largely upon the weather conditions, and this is another factor of the shrinkage. An embankment put up during wet weather will stand better than one of the same material made in the same way during dry weather; in fact many embankments constructed during very wet weather settle but little after completion. Frozen material deposited in any manner will always settle a great deal when it thaws out. Embankments made of any dry material except rock, by any of the methods, will not shrink to their final volume until after they have been pretty thoroughly soaked with rain water.

Practically all of the shrinkage in earthwork takes place vertically, and in railroad construction it is customary to build the embankments high enough above the permanent grade line to allow for settlement. In consideration of the several varying factors as above explained, it is readily seen that the amount of shrinkage to allow in any particular case must be determined largely in the judgment of the engineer acquainted with the conditions. This explains why different persons of limited experience who have sought to reduce such problems to set rule have produced widely varying or conflicting figures. All rules on shrinkage of earthwork must be construed liberally and in light of the attending conditions. With this understanding the following allowances may be considered approximate guides in general cases under normal conditions: for sand and gravel embankments put up with drag scrapers, 1 to 3 per cent; for clay and loam handled in the same way, 3 to 5 per cent; for wheel scraper, cart and wagon work in horizontal layers, 2 to 7 per cent, according to the character of the material; for material dumped from cars on trestles, 6 to 8 per cent; for embankments extended by dumping over the end, from grade, out of carts, wagons or cars, 6 to 10 per cent., according to the character of the material; for wheelbarrow work or hand casting, 12 to 25 per cent. Embankments made with grading machines are at first fluffy and covered with lumps, but it is customary to follow up such work with a harrow and a road roller, to even up and compact the surface. There is some disagreement as to whether or not the percentage of settlement with high embankments is greater than with low ones, after completion, and data have been produced to prove either view. It is quite probable that here again the method of construction, and also the time factor, may have much to do with the question. For instance, the comparison of high and low embankments built up by team work in horizontal layers might not be the same as with embankments of corresponding hights built with material dumped over the end, from grade. In the one case the material throughout the embankment becomes quite solidly compacted as the earthwork rises, while in the other the compression of the material in the bottom of the bank depends entirely upon the weight of material above, which, of course, is greater the greater the hight of the embankment. It seems reasonable to suppose that, ultimately, the percentage of settlement must increase with hight of embankment, but it might not occur in every case that the disproportion would be discoverable after the completion of the work. The time consumed in constructing the higher of two embankments might also be so long that much of the material would find its bearing in considerable measure before the completion of the work. Another matter to consider in this connection is the character of the bottom on which the embankment is built. On a yielding bottom the settlement of the natural surface under the weight of the embankment may be very considerable or even exceed the shrinkage of the material of which the embankment is composed. Such effects, of course, increase with hight of embankment.

The allowance for shrinkage of embankments has frequently been a source of trouble between contractors and the parties for whom the work was done, but if the plan is followed of paying for earthwork in the excavation the shrinkage is not then a matter of live concern with the contractor. In relocating parts of the line on its Wyoming division the Union Pacific R. R. built a number of very high embankments, and on these allowance was made for shrinkage without carrying the earthwork above the established sub-grade. The plan followed in this case was to estimate the probable shrinkage or settlement and then make the top width, at sub-grade, equivalent to what the width of the embankment would be at this level if the earthwork was built up sufficiently high to allow for the estimated shrinkage and made standard width at that level. This provided an embankment which would be wide enough after settlement to hold the filling material required to raise it again to the established sub-grade. The extra width of the top of the embankment, as constructed, was provided for by making the slopes steeper than the standard inclination, which was 1½ to 1. This scheme in no case increased the slope beyond 1.4 to 1, and as these slopes flattened as the embankments settled there was no trouble in maintaining them. The idea in this plan of work was to avoid the possibility of getting the embankments permanently too high by overestimating the shrinkage, and also to avoid widening the base of embankments to provide for shrinkage, which, from the fact that shrinkage is vertical in every case, is not necessary.

Embankments built up in layers extending the full width of the cross section shed water much better than those made by dumping over the end or side; and if these layers are crowned at the middle the embankment will drain out better than it will if the layers are horizontal or dishing. It is well, in any method of building an embankment, to keep the middle of the filling all the while somewhat higher than the sides, so that any tendency to the formation of layers will result in lines or courses which slope toward the exterior. This matter may be placed in charge of the man who trims out the fill and, by a little attention, is easily looked after at no additional expense. It helps toward the regularity of the layers to roughly level down the peaks of heaps of material dumped, although no considerable amount of time need be spent at it. The filling in rear of abutments and retaining walls should be deposited in layers generally not to exceed 1 ft. thick, well compacted and inclined away from the masonry.

Particular care should be exercised to avoid the formation of hard, steep slopes or cleavage planes within an embankment. Such faulty construction is most likely to occur where different kinds of materials, or materials from different sources, are used for filling at various stages of the work. A brief account of an interesting experience in this line on the Minneapolis & St. Louis R. R. will serve to illustrate the practical workings of a case in point. The facts were kindly supplied me by Mr. H. G. Kelly, chief engineer of the road. An embankment about 1000 ft. long and 25 ft. high, constructed less than four years, began to give trouble by sliding, and in attempting to remedy the matter by dumping more material upon the slidden portions of the embankment something like

$10,000 was expended without accomplishing the purpose sought. Investigation disclosed that the embankment had been formed of light clayey loam hauled from cuttings and deposited upon a substratum of heavy blue clay scraped up from borrow pits. The seat of all the trouble was found by excavating into the bank, when it was discovered that a well defined plane of cleavage existed between the two materials, coinciding with the inclined runway of the scrapers used during construction. The sliding of the embankment had taken place upon this inclined plane. The trouble was permanently cured by heroic treatment, at a total cost of $1200, in the following manner: During dry weather longitudinal trenches were excavated on the side slopes, near the foot of the embankment, on either side, and between these two trenches cross trenches 2 ft. wide and 10 ft. apart were cut through the embankment and carried down below the so-called plane of cleavage. Meanwhile the track found support upon an improvised trestle formed by placing long stringers upon two-pile bents which had been driven when the sliding became serious, prior to the excavation work, resort to this means of support being taken to carry the trains. The trenches were then filled with pile heads and old ties and covered over with the clay excavated from them. This mass was then fired, more clay being added as the burning material in the trenches settled down. The embankment smoldered away like a charcoal pit for six weeks and the bank was burned into a solid mass of brick, never to slide again. Following the result of this experiment the same method of treatment has been applied to other embankments on this road containing clay, with uniformly successful results. Where filling is to be done on a steep, hard slope, as on side hill, it is well to break up the cleavage plane by cutting lines of steps in the slope, to bind the new material. In most cases this may be done sufficiently well by plowing deep furrows several feet apart. To prevent the slopes of filling material from sliding it is sometimes the practice to dig a trench just inside each toe line of the embankment, but with material of approved quality such precaution is not necessary.

Large stones should not be placed in shallow fills, and when such are found above the surface, on location, within 2 ft. below sub-grade, they should be broken up, rolled into pits or rolled outside the slope stakes. Stumps should be cut off at least 2 ft. below sub-grade, but wood which rots quickly should not be permitted to remain in a fill at all, except, perhaps, in the case of an embankment formed upon a steep hillside—where the trunks of all large trees which stand within the slope stakes should remain standing, to assist in retaining the earth and prevent sliding. Just before the embankment is completed or at that time the trees may be cut off at proper distance under sub-grade, or even with the slope. It is usually required that large trees shall be cut so that the tops of the stumps shall not be more than 3 ft. above the ground, and that where embankments are less than 3 ft. in hight all trees and stumps shall be cut close to the ground. The surface of ground to be excavated and where embankments less than 2 ft. in hight are to be built should be grubbed free from stumps, roots and other perishable material, and all brush should be cleared away. In some cases where the materials vary considerably it is advisable to reserve the best of them for finishing and dressing the surface. In a wooded country, where grading is done by contractors, especially when sublet to numerous subcontractors, it is well to keep close watch to see that logs are not rolled in and covered up. One is justified in being suspicious of all filling done at night or not during regular working hours. Aside from rotting and weakening the fill years afterward, or burning, in case the ends get uncovered, a fill containing many logs, especially where several are rolled together in a heap, or are near the top in any shape, will be springy or humpy and a positive hindrance to good surface for a long time.

The top surface of roadbed should be graded off smoothly, filling up all pockets or depressions which would otherwise remain to collect and hold the water which sinks through the ballast, where it can freeze in in winter time and heave the track. For this reason ruts from wagon wheels driven over the roadbed should be filled and the material compacted before the track is laid or the ballast deposited. The practice of running material trains over newly laid track before it is surfaced or ballasted also requires that the roadbed surface be made smooth, to afford an even embedment of the ties and thus avoid kinking the rails.

As far as possible, embankments or other made ground should be completed early, so as to have time to settle before the track is laid. Embankments seldom settle evenly, and track laid thereon before settlement does take place is sure to require considerable labor to keep it in fair surface soon after the trains begin running. Where a short fill comes between two cuts or next to a bridge it should be put high enough to allow for settlement. If not, the fill will settle below the established grade, while the roadbed in the cuts or the track on the bridge will not, and there will then result an ugly sag.

The slope of railway embankments varies from 1 to 1 for rock fills to 1½ to 1 for ordinary earth, and easier slopes for soft material like clayey soil, when such must be used. By building up a rough dry wall on the exterior of a rock fill it may be made to stand at a slope somewhat steeper than 1 to 1. Ordinary earth will stand for a time at a slope steeper than 1½ (horizontal) to 1 (vertical), but under the action of the rains, the winds and frost it will gradually wear down to about 1½ to 1. In excavations, solid rock which will not disintegrate by exposure will stand to a vertical face. Firm dry earth well protected from water seepage is sometimes sloped 1 to 1 in cuttings, but under less favorable conditions it will not always stand at even 1½ to 1. Under ordinary conditions, however, 1½ to 1 is considered safe. Where excavation is made through rock overlaid with earth, the earth slope should be cut back to leave a berm of 3 to 4 ft. from the brink of the rock slope, to retain loose material which slides or rolls down in moderate quantities. The slope of earth in such places should be made easier, if anything, than elsewhere, because rock cuts are usually made so narrow that only a relatively small amount of material sliding into the same is liable to fill the ditch and obstruct the rail.

Sub-Drainage.—A question which has received but little attention from American railway engineers as yet is the sub-drainage of roadbed. Although the value of sub-drainage in wet cuts is recognized, and in comparatively few cases something has been done to put the principle into practice, but little or nothing has been done to carry the water from embankments by under drains. In selecting material for ballast the drainage feature is considered one of the most important properties, but it should be understood that drainage as applying to ballast refers to the drainage of water from the ties *to the roadbed.* Through stone ballast, for example, water sinks to the roadbed as through a sieve, and in gravel ballast the same thing occurs after the material becomes thoroughly soaked. The sand contained in gravel has, of course, some capacity for holding the water back. Such being the case the roadbed under most of the track which is considered well ballasted must receive a good deal of water. So far as ballast is concerned it reaches its limit of settlement within a comparatively short time, and those who will investigate matters closely will find that rough surface in old track is caused largely by settlement of the roadbed or settlement below sub-grade. One very responsible cause for this condition is the seepage of water through the ballast and into the roadbed. While much of this might be drained off on the top surface of the roadbed, if the same was properly crowned, it is known, nevertheless, that only a comparatively small amount of roadbed construction is brought to such a top surface and compacted sufficiently to hold its slope until the ballast is placed upon it; and in many cases, as already shown, it is impracticable to do this. As a rule, then, a good deal of water must find its way into the interior of the roadbed to soften the material and keep it continually settling, and, in cold weather, to freeze and heave the track. Moreover, as most double-tracking is done by building a second track beside the old one, it is impracticable to crown the roadbed midway between the tracks and slope it to either side, since the roadbed at subgrade under the old track, if properly formed, is highest underneath the center of the track and, in any case, it is not accessible. Such being the case one has good reason to think that most of the water which finds its way through the ballast on double track percolates through the roadbed material to considerable depth.

The value of tile drainage being well understood, there would seem to be no difficulty in keeping the interior of the roadbed reasonably dry by resorting to the usual methods of sub-drainage. It would certainly be worth the cost of thorough trial, on any railroad where the annual rainfall is considerable, to see if a longitudinal tile drain laid a few inches under sub-grade, with cross drains leading to the surface at frequent intervals, would not intercept the larger portion of the water which ordinarily sinks through the roadbed. On single track such a drain might be laid under the center of the track, preferably in sections draining into the cross drains at a considerable fall rather than in a continuous line laid to the grade of the track, except perhaps on the steepest grades. On double track, where the roadbed is constructed before either track is laid, and properly crowned in the middle, a line of tile might be laid under the center of each track, but otherwise, as in the case where the two sides of the embankment or cut were formed at different times, only one drain would likely be used, and that could be placed to best advantage midway between the tracks, or about on the dividing line between the old and new embankments. On the double-track lines of the Baltimore & Ohio R. R., where stone ballast is used, an 8-in. tile drain is laid upon the roadbed midway between the tracks and the ballast is filled in level with the tops of the ties. The roadbed is crowned 6 ins. in the middle and the depth of ballast at this point is 12 ins. below the bottoms of the ties.

Sodding and Seeding.—Still another line in which the maintenance of earthwork is open to improvement is the protection of slopes against washing or sliding, by the growth of vegetation. Barren embankment slopes are continually eroded by rains, and ditches at the bottom of bare slopes in cuts become obstructed by sediment washed down by the rains or which rolls or slides down when loosened by the thawing of the ground. On English railways the sodding of slopes is a feature of general practice, but in this country it has been considered too expensive to have succeeded to anything like extensive trial. Here and there the slopes of a cut will be found sodded, but in general practice the natural growth of weeds or grass, without any attempt at encouragement or cultivation, is all that can be found on either cuts or fills. A healthy growth of grass on slopes requires nourishment by a coating of soil. In cuts this may sometimes be obtained by stripping the top surface some distance back from the cut. The best opportunity to obtain the material on the right of way, however, is before the cut is excavated. The top soil is scraped back beyond the slope stakes into heaps and after the excavation has been completed it can then be spread over the slopes that are to be sodded or seeded. On embankments the strippings from gravel pits, material cleaned from ditches, the bedding from stock cars, and other fertile material which must be hauled off for disposal may be utilized to encourage the growth of vegetation. Sweepings from streets are also good material for this purpose, as they contain a large percentage of fertilizing matter and a considerable mixture of seeds of various kinds.

Before sodding or seeding is begun the slopes should be dressed off reasonably smooth and angular shoulders and intersections at the top and toe of slopes should be rounded off to a natural contour. Sods about five years old are the most vigorous for transplanting, and those from high, well drained ground are, from previous condition of growth, better able to thrive on dry slopes than sods from swampy or wet localities. As a means of assisting the sod in getting started some recommend sowing a mixture of timothy seed and oats over it the first year. These will quickly spring up and form strong roots to help hold the sod in place. To strengthen the growth later on, Kentucky blue grass, white clover, perennial rye, red fesco and red top, in the proportions of 8, 4, 9, 3 and 8, respectively, are considered a good mixture for supplemental seeding. In the South the slopes of embankments are frequently set with tufts of Bermuda grass in rows 1½ to 2 ft. apart, as referred to in §148. This grass will thrive in sand, and in a short time it forms a thick sod entirely covering the ground. Its characteristics are described in §12, in connection with sand ballast. Where sod is placed on steep slopes it is customary to drive stakes, in rows, staggered, to hold it in place until the roots take firm hold. The stakes are usually driven flush with the surface of the sod and permitted to remain. Seeding is, of course, cheaper than sodding, but some time is required for the growth to form a sod. The variety of seed best suited to the climate and soil is perhaps best ascertained by observation of the natural growth or of the grasses grown under cultivation in the locality. Willows and scrub brush indigenous to the locality are also planted on slopes to check the tendency to slide or wash away. An advantage in a growth of willows is that their great vitality permits close trimming, forming in time heavy stumps and strong roots to permeate the ground and hold it in place, without the presence of an excessive or troublesome growth above the surface.

Borrow Pits.—A matter which ought to receive more attention than it sometimes does with fills made from borrow pits, is the nearness of the pit to the foot of slope. At the foot of slope of shallow embankments, say up to 3 ft. in hight, there should be a berm at least 4 ft. wide; and for higher embankments the berm should be wider. The removal of earth in nearness to the foot of slope increases the hight of the embankment by the depth of the pit excavated, and if the pit is too near it of course weakens the embankment. It is also to be considered that with a narrow berm ties and other materials thrown off the cars will slide or roll out of reach; and besides, if the embankment must ever be widened, a pit at the foot of slope must first be filled before an addition can be made. In improving the grades of a line it is not unusual to raise the track as high as 4 ft., increasing the hight of the embankment that much, which means a widening at the foot of slope of about 6 ft. It would seem like good policy, therefore, to be mindful of a good factor of safety in establishing the width of berm, making it at least 8 or 10 ft., wherever practicable, and always leaving room for a double track on one side. The standard cross section of the Union Pacific R. R. provides for a berm 6 ft. wide on one side and 18 ft. wide on the other side, as the probable base for a widened embankment for a second track. The standard plans of the Kansas City, Pittsburg & Gulf R. R. require berms 6 ft. wide for banks 15 ft. high or less and 12 ft. wide for banks higher than 15 ft. The standard berm of the New York Central & Hudson River R. R. is not less than 6 ft. wide in any case, nor less than double the depth of the pit or ditch, always leaving room for double track on one side. On the above-mentioned considerations it is just as important that the berm should be guarded against depletion as that it should be established at proper width in the beginning—which is to say that the berm should not be cut away to "build up" the bank.

Borrow pits, or ditches from which material is taken for shaping up banks, are frequently left by the construction forces in an unsightly condition, being excavated on irregular lines and to irregular depths, and without sloping the sides. Properly, the sides of borrow pits should be trimmed up parallel with the alignment, and the side next the track should be given a natural slope, according to the character of the material, never steeper than 1 to 1 for earth, and usually 1½ to 1 or the same as the slope of the embankment. The drainage of borrow pits close to embankments should also be looked after, and the proper time to do this is, of course, when the pit is being excavated. In most instances the pit may be so located that the excavation of the same will provide an outlet, or the excavation for an outlet to the pit may be made to supply part of the borrowed material. Water standing in a borrow pit at a higher elevation than the surface of the right of way on the opposite side of the embankment will naturally seep strongest in that direction, thus tending to soften the earthwork foundation.

Roadbed over Marsh Land.—Aside from the nature of the fill itself the ground upon which it is made is sometimes so unstable that proper support for the track cannot be easily obtained. Such is frequently the case in swampy or boggy land and on quicksand. On an easily yielding surface a shallow fill will roll up ahead of a train and give way underneath it, without remedy. Under such circumstances it becomes a difficult matter to maintain the track in fair surface, and the rails will creep badly. There are several measures which may be taken to overcome difficulties or improve the conditions in a situation of this kind. In the first place, before attempting to fill across a swamp or bog the region should be drained as thoroughly as may be feasible, and in order to accomplish this it is sometimes necessary to undertake the drainage of a large area, by extensive excavation distant from the right of way. The hope of accomplishing results on this line of operations lies, of course, in the amount of fall obtainable. It is then important to look carefully to the drainage near the track, usually by cutting ditches of good depth as near the embankment as the conditions of stability will allow. The Galway & Clifden Ry., in Ireland, runs through long stretches of bog land and the matter of drainage and types of roadbed construction have been closely studied. On this road the standard arrangement for drainage consists of two longitudinal ditches 22 ft. apart on each side of the track. The inner ditch on each side is 4 ft. wide at the top and 3 ft. deep, and is cut at a distance of 6 ft. from the toe of the embankment. The outer ditch is 6 ft. wide at the top and 5 ft. deep. The side slope of these ditches is 1 in 3, and the two are connected by cross drains every 100 ft.

In filling over boggy land it will usually pay better to haul the filling material some distance than to use the top surface of the swamp, as it is seldom fit for constructing embankments. The best results are obtained by leaving the top surface under the roadbed undisturbed, as it usually consists of matted vegetable matter which will carry a considerable weight without breaking. To secure a proper distribution of the weight the filling material for the embankment is sometimes deposited upon a corduroy foundation, but more frequently upon a brush mattress. In making embankments over marshy land in Holland it is quite commonly the practice to first lay a mattress of willow boughs, 2 to 4 ft. thick, extending from toe to toe of the embankment slopes, before the earth filling is begun. On the Galway and Clifden Ry. a layer of brushwood and poles 3 ft. thick has been used as a foundation for embankments on bog land, with satisfactory results; but the most successful construction in this line is reported to have been obtained by building the embankment with turf, without brushwood, and then covering it with an 18-in. layer of stiff, marly clay, which hardens upon exposure to the air and becomes water proof. A source of trouble to be guarded against with embankments made by filling over a peat bog is fire. In extremely dry weather peat, especially in a bog which has been drained out, will sometimes take fire and burn over large areas, smoldering away for weeks. It is something of a task to extinguish such a fire, as it will burn on in spite of light rains, and if not stopped in some way will burn right under an embankment and let it down. About the only way to fight it is to dig a trench across its path.

Where the yielding material in marshy land is shallow or extends but a few feet below the surface, the stability of an embankment constructed thereon improves with increase in hight; but if the yielding material extends to considerable depth any increase to the hight of an embankment only makes matters worse. In the latter case the weight of the superimposed embankment causes it to sink into the mass of yielding material, the displacement of which usually takes an upward course, bulging the ground on either side of the embankment. Not infrequently a large mound will be formed at either side of an embankment which has settled in this manner, sometimes overthrowing right-of-way fence and telegraph poles or carrying them out of line. A remedy sometimes applied is to drive a row of piles a few feet apart along the foot of each slope of the embankment. As a better means of preventing settlement it has been proposed to construct a sort of pier as a foundation for the embankment, by driving a row of piles outside each line of slope stakes and placing a line of timber inside each row of piles as backing for a row of sheet piling. It is proposed to then tie the two rows of piling together with rods and in this way prevent the mucky material underneath from getting away. The practicability of this scheme would, of course, depend a good deal upon the depth of the marsh. On ground of this nature, however, it is sometimes better not to fill at all but to build the track on piling.

Where the track must run but a few feet above the surface of a marsh, and piling, for some special reason, is impracticable, a substructure which will bear up evenly under the track may be made in the following manner: Grade off the top surface just enough to get a fair bearing, and upon it lay closely, thick, wide cross ties 12 or 15 ft. long. Upon these place deep stringers of good length and lay them to break joints. Use about as many as would be required to support the track on piling. Upon the stringers place sawed cross ties and drift-bolt them, and lay the track about as it would be laid on a bridge floor. Each bottom tie should be made to lie in as good a bed in the mud as may be, without special reference to the other ties each side of it. The stringers can be evenly supported by spiking shims of proper thickness to the tops of such ties as are not touched by the stringers after they are put to place and leveled up. In this manner the stringers transmit the weight over a larger surface than a shallow earth fill can and, when properly made, will maintain track in quite even surface. The stringers should be braced to a portion of the ties underneath them to keep the track in alignment. The structure is simply a track built with a double course of cross ties with stringers between the two courses. It is to be expected that there will be more spring in such a structure than in track supported on piles.

Before roadbed construction through marshy land is undertaken soundings should be made by a portable pile driver, or other means, to ascertain the conditions underneath. If the material underneath is found to be extremely soft or readily yielding to a considerable depth, it is well worth while to consider the alternative of either abandoning the location or resorting to pile construction. The sinking of embankments into marshy ground is not of unusual occurrence. It has frequently happened that fills made through swamps or bog land or over strata of quicksands have displaced the underlying materials and entirely disappeared. Difficulties of this kind have sometimes been met by continuing to deposit filling material until equilibrium was obtained between it and the material which it displaced, but in numerous instances large sums of money have been expended in this way only to abandon the work in the end. In cases of this kind the most serious trouble has not usually developed until after the roadbed was subjected to the weight and jar of passing trains, but proper examination beforehand, at nominal expense, might have disclosed the exact nature of the conditions. The perplexity of dealing with such conditions has, in a large number of instances, convinced maintenance of way men that the most satisfactory practice lay in the permanent use of piling and in foregoing any attempt at earthwork. It will be interesting to give here the particulars in a case or two of the kind under consideration.

In the summer of 1897 the Chicago, Indianapolis & Louisville ("Monon") Ry. made extensive changes in the location of its line in the vicinity of Cedar Lake, Ind. A stretch of track about 300 ft. long, on the old location, crossed the eastern side of a marshy basin, generally circular in shape and about 1,000 ft. across. In eliminating a curve the track at this point was relocated farther over, so as to cross about 800 ft. of the marsh, on a line running 125 to 200 ft. distant from the old location. Filling material was obtained from a heavy cutting to the south and work had progressed on the construction of an embankment, with teams, for a period exceeding a month, during which time a fill about 7 ft. in hight had been extended nearly half way across the marsh. No unusual settlement had apparently taken place, when, upon taking up the work one morning, it was found that 150 ft. of the fill had sunk about 16 ft. and disappeared under a depth of 7 ft. of water. This, the first subsidence, is shown in Fig. 1, the bottom picture being a nearer view looking down into the depression. The track appearing in the background of this view was the old main track, about 125 ft. distant, which had carried traffic for years without extraordinary settlement. The work of filling was next taken up from the north side of the basin, the material being hauled out on cars which were unloaded from a temporary trestle. After considerable progress had been made this embankment also disappeared, carrying the trestle and track with it so suddenly that a train of cars which was being unloaded at the time was barely saved from sinking with the track. This part of the fill also sank beneath the water and no trace of the track was afterward discovered. The sinking of the embankment caused the surrounding surface to bulge upward, and large cracks 6 or 7 ft. deep were opened up along the lines where the top stratum was sharply broken off and deflected downward by the sinking of the earthwork. These cracks revealed a bed of peat extending the whole depth and below. The surface of the water which covered the sunken embankment was 2 or 3 ft. below the general surface of the marsh. Moisture was absent on the top surface, as may be surmised from the fact that at the time the photographs were taken the peaty surface was afire and was burning over a considerable area. The hazy appearance in the background of the illustrations is due to smoke arising from this burning peat. There was no water in sight at any point on the marsh and the land was enclosed and used for pasture. Judging of the nature of the deeper earth structure from the foregoing suggestions of instability it was decided to abandon the project of filling and carry the track across on piling. Something of the nature of the underground support may be inferred from the fact that the piles had to be driven to depths varying from 75 to 150 ft. in order to secure bearing of sufficient supporting power. The piles used were of oak in 25-ft. lengths, spliced by cutting off squarely and joining end to end, using a drift bolt, and two iron straps bolted through and through at each joint. The pile driver which appears in the illustrations had progressed with the work of bridging across about one-half of the affected territory.

A most remarkable and strange circumstance associated with the sinking of this earthwork was that immediately following the first subsidence the water covering the sunken embankment was thickly populated with

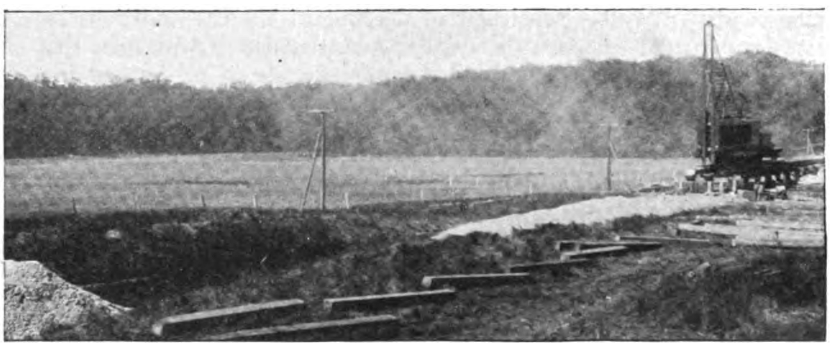


Fig. 1.—Sunken Embankment, C. I. & L. Ry.

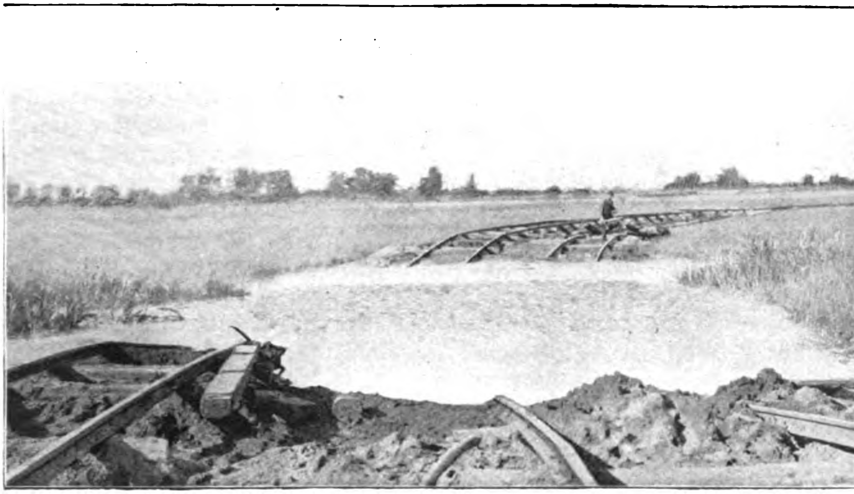


Fig. 2.—Sink Hole, Grand Rapids, Holland & Lake Michigan Ry.

fish and frogs. The fish were of all sizes, from minnows to fish 6 or 8 ins. in length, and there was no peculiarity of eye structure such as is commonly found with subterranean varieties. There was apparently no grounds for explaining the presence of these aquatic inhabitants on the theory of an underground passage, for there was no near body of water on the same level containing fish. The surface of the water in Cedar Lake, one mile distant, is 28 ft. below the water level at the point of subsidence, as determined by the railroad surveys, and the track between the two points is on a grade of 26 ft. per mile. The only satisfactory explanation is that at one time an open body of water existed in this basin, and that within a comparatively recent period it was gradually overgrown with a thick bed of peat moss, the surface of which, over the whole area, is now found in the decomposed state, or in the form of peat. The looseness of structure in places would admit sufficient air to maintain the life of fish descended from the earlier inhabitants of the open water, and enable frogs, by burrowing, to exist on water which did not appear at the upper surface. There are lakes in this country where growths of this kind may now be seen in progress. Beds of moss of astonishing depth have become extended from the shores and are slowly spreading over the surface of deep water. In some cases these floating beds are so firm and their buoyancy so great that one might readily mistake them for the real shore of the lake. This fact explains why railway embankments sometimes sink so suddenly. So long as the floating crust can bear up the material filled upon it, the settlement may not be excessive, but when the conditions of support or the increase of load become such that the crust breaks through, the sinking of the embankment then takes place suddenly.

A case similar to the foregoing, but more nearly in line with ordinary experience, occurred some miles west of Chicago, on the Chicago, Burlington & Quincy Ry., in 1890. In making a fill for an additional track beside an old embankment the earthwork settled 1 to 3 ft. per day. By persistently filling, however, until the track had settled altogether about 40 ft. and 95,000 cu. yds. of gravel and dirt had been dumped into an embankment 1000 ft. long, the settlement finally ceased. The earth on each side of the embankment was crowded outward and rolled upward in a ridge 10 ft. high, and the telegraph poles were moved 12 ft. farther from the track. It is probable that the settlement did not cease until the new embankment found bottom on bed rock or upon a hard stratum. In filling for an embankment on similar ground at Barclay, Ontario, on the Canadian Pacific Ry., it was estimated, from the amount of material required, that the depth of the "muskeg" must have been 200 ft. Figure 2 shows a sink hole on the Grand Rapids, Holland and Lake Michigan Ry., near the city limits of Holland, Mich. Only a short time after the tracks had been laid the entire roadbed sank completely out of sight in the marsh, only a pond of water remaining visible at the surface. The distance across this sink hole was 700 ft., and an attempt was made to fill it with sand and gravel, but seemingly there was no bottom, and this method had to be abandoned. Support for the track was finally provided by building a pile trestle with 30-ft. piles spliced together.

Instances of extraordinary settlement or sinking of roadbed in marshes have been numerous. An account of several occurrences of this kind in Pennsylvania, New Jersey and New York may be found in the Railway Review for Nov. 21, 1891. The usual remedy is either a pile trestle or filling material in sufficient quantity to "strike bottom." A plan followed on the Detroit & Milwaukee R. R. in crossing a sink hole 2600 ft. long and 60 ft. deep, 6 miles east of Grand Rapids, Mich., was to make a slab raft 10 ft. thick and fill on top of this with sand. There was some difficulty from the tipping of the raft in sinking, but in the end the work was successful.

4. Ditches.—By proper drainage of the roadbed and track much expense which otherwise might be incurred in keeping the track to surface can be saved. Water must be kept out of, or drained away from, the ballast as much as possible, to keep it from softening and settling or to prevent it from freezing and heaving in winter; the roadbed must, for the same reasons, be protected. The proper form, depth and size of a ditch and its distance from the ties depend a good deal upon surrounding conditions. First of all, most of the ditches that are needed are located in or around cuts. A very important ditch at a cut, if it be a sidehill cut or wherever the general surface of the ground slopes toward the cut, is the surface ditch, along the upper side, the purpose of which is to intercept surface water and divert it from the cut. The size of a surface ditch must depend upon the amount of land to be drained. Ditches of this kind must sometimes be made as deep as 5 or 6 ft., and correspondingly broad, in order to afford sufficient capacity for the large amount of water which comes in torrents during hard rain storms. The ditch should stand a good distance back from the top of slope, say 10 or 15 ft., and the dirt taken out of it should be heaped up on the side toward the cut. Where such ditches are too close there is danger that the seepage of water from the bottom of the ditch will soften the earth and cause slides. Spoil banks or material wasted in the excavation of cuts should be a good distance clear of the slope stakes, say at least 15 ft. In matters of this kind it is well to have in view a safe margin to cover possible improvements, such as the widening of cuts for more ditch room or for laying a second track or to obtain easier slopes. The surface or "top" ditch should be run each way from the lateral watershed to the nearest culvert or other opening under the track; or, at all events, the ditch should be so diverted that the water discharged will not find its way into the roadbed. Where the slopes of a cut are springy it is sometimes the practice to cut diagonal ditches down the slopes, at easy grades, to prevent excessive wash. Where springs of considerable size gush out of the slope the best way to take care of them is to lay lines of drain tile to conduct the water directly or diagonally down the slope and into the ditch or under drain. If the slope of the hillside is a long one it is well to have a second surface ditch farther up the hill, to catch the larger part of the flow during heavy storms. By properly ditching the region above the track much water which would not appear upon the surface directly above the cut, but which, nevertheless, would find its way out at the face of the cut, can be turned aside. Cases of this kind are on record where cuts, which beforehand had been wet and bothersome, have, by surface ditching, been made nearly or quite dry.

Drainage Conditions as Affecting Land-Slides.—Roadbed in side-hill cuttings through clay sometimes gives way and slides down the hill, carrying the track along; likewise slides from above become troublesome when water gets between the strata underneath the surface. In cases of this kind it is well to keep water out of the cut, as far as possible, and make search to see if by draining out some pond or swamp at a higher level the water can be prevented from soaking through the ground toward the cut. Clay, if kept dry, is tough and will sustain pressure very well, but when wet it becomes plastic and will slide down the slightest grade if not confined in some way. Much of the region surrounding the Puget sound is of clay formation and has presented special difficulties to many kinds of engineering work requiring good foundations; all the more so, too, because of the large and long continued rainfall in that region. Railroad ditching properly done means the draining of a large area, sometimes.

A good illustration of the influence of seepage on earth movements is to be seen on the Canadian Pacific Ry., along the Thompson river, about 200 miles east of Vancouver, B. C. Owing to the irrigation of terrace lands some remarkably large land-slides were developed in this locality before the railroad was built. One of the slides was about ½ mile wide and ¾ mile long, back from the river, and covered an area of 155 acres. This enormous mass of earth dropped vertically, in one movement, to a depth exceeding 400 ft. at the back edge, and the lower portion was pushed ahead until it came to rest against a steep bluff on the opposite side of the river, damming the river to a hight of 160 ft. and forming a lake 12 miles long. As soon as the river rose above this dam the water cut its way through and the loose material was all swept away. About a mile distant another slide occurred having a width of 1880 ft., a length back from the river of 1575 ft. and covering an area of 66 acres. Within a distance of 6 miles there were four other large slides, across all of which the road had to be constructed, following closely the contour of the river bank at an elevation of 50 to 80 ft. above low-water level. The material composing these slides consists of soil overlying strata of sandy loam and clear sand, below which the material is stratified gravel and boulders. The whole rests upon a stratum of clay silt, and it was upon this material that the sliding took place. The slide at each point occurred between three and six years after irrigation began. The largest slide above referred to was hastened by the bursting of a reservoir two miles distant in the hills, which poured a flood of water upon fields that had already become well soaked. As all the arable land at this point was carried down with the slide the irrigation was stopped and in the course of a few years the water drained out so completely that movement ceased and no trouble with the track has occurred. At the other slide, however, there has been continued application of large quantities of irrigation water upon the cultivated fields above the slide and in consequence the track has been continually pushed toward the river, sometimes at the rate of 8 ft. in one night, the roadbed sinking at the same time as much as 4 ft. As the material has been forced forward the river has washed it away, and from time to time a new roadbed has been built further back and the track moved over to it. This portion of the road has had to be carefully watched, and in order to maintain a safe passage across the line dividing the stable from the moving material the track has had to be continually shifted.

Track Ditches.—The office of a ditch near the track, sometimes called the "track ditch," is to drain off the water which falls upon the track and that which runs toward it from the side. As the roadbed is subject to seepage from the water collected the drainage conditions naturally improve with increase of distance between the ditch and the track. Reference is limited to comparatively near distances, of course, and, standing in some relation to depth of cut, there is a limit of excavation to be calculated upon, at which the interest on extra capital invested to save repairs will balance with the saving so made. Beyond this limit engineers are not supposed to go, unless the extra material excavated can be disposed of to advantage. An important study in problems of track engineering is to find the proper balance between efficiency and economy. Thus, under certain circumstances, it might pay better to leave some cuts at a minimum allowable width and, with the saving in expense so effected, widen others out to exceed standard dimensions, possibly, than to make all of the cuts the same width merely for the sake of appearance or of conforming to some adopted standard. To put upon paper the form and dimensions of a ditch, called a "standard" ditch, and to suppose that it will meet all the conditions economically, may be landscape gardening but it may or may not be good engineering. The idea of standardizing is a valuable one if it goes far enough to provide a standard for each of the several conditions requiring different methods of treatment.

Forms of Ditches.—In a general way ditches take two forms, according as the roadbed is shouldered or not. Where the roadbed is not shouldered the ditch is formed by sloping the roadbed at the sides to meet the toe of the slope of the cut. At the ditch it is usual to increase somewhat the general side slope of the roadbed due to the crowned center, so as to gain depth for the ditch. Ditches of this form are most commonly found in narrow cuts, where there is not room to shoulder the roadbed and cut a ditch beyond the same. On some roads, however, this form of ditch is preferred for any width of cut, the advantage claimed being that such is the natural form; and that if a shoulder is interposed between the track and the ditch it will eventually become rounded off or worn down to a common slope from the track to the back side of the ditch. The following are some of the roads on which this form of ditch is standard, the width of single-track roadbed, from toe to toe of slope, and the depth of ballast under the bottom of the tie being given in each case: Southern Pacific, roadbed 16 ft. (18 ft. in regions where rainfall is heavy) ballast 8 ins.; Erie, roadbed 18 ft. 8½ ins., ballast 12 ins.; Atchison, Topeka & Santa Fe, roadbed 26 ft., ballast 10 ins.; Cincinnati, New Orleans & Texas Pacific and Baltimore & Ohio roads, roadbed 18 ft., ballast 12 ins.; Pennsylvania (light-traffic lines), roadbed 19 ft. 2 ins., ballast 8 ins.; Philadelphia & Reading (in dry cuts), roadbed 18½ ft., ballast 8 ins.; Southern Ry., roadbed 18 ft., ballast 6 ins.; Missouri, Kansas & Texas, roadbed 18 ft., ballast 6 ins. On this road a middle strip of the roadbed 8 ft. wide is flat, the slope into the ditch (6 to 1) starting under the ends of the ties. On each of these roads except the Southern Pacific the ballast is either shouldered out beyond the ends of the ties or at least filled in against the ends. On that road broken rock ballast is dressed in this way but gravel ballast is not.

The other of the two forms of ditches here considered is made by constructing a roadbed of ordinary width, at sub-grade, as on embankment, and then excavating the ditch beyond the shoulder. The idea in constructing a ditch in this manner is to remove the water as far as possible from the ballast. Ditches of this form are either V-shaped or trough-shaped, the latter having a flat bottom. As between two ditches with the same side slopes the flat-bottomed one will, of course, carry more water for the same depth than the one that is V-shaped. Some prefer the V-shaped ditch, however, because it takes up less room and so concentrates the flow of water that it is more likely to keep itself clear, especially where the flow is small. On different roads the width of single-track roadbed with V-shaped ditches varies from about 19 ft. to 28 ft. from toe to toe of slope, although in some cases it is less than 19 ft. The toe-to-toe width of roadbed with trough-shaped ditches varies from about 22 to 28 ft., for single-track roads, although both wider and narrower measurements may be found, in cases.

Size of Ditches.—The width of roadbed in cuts and the size of ditch should be governed to some extent by the depth of the cut, because a long slope brings more water to the ditch than a short one, and consequently more sediment; hence the larger the ditch the less will be the trouble to keep it clear. In cuts of extensive length it may also be found advisable to increase the capacity of the ditches toward the outlet. All things considered, 18 ft. should be about the least allowable width of roadbed in cuts, and then the conditions must be favorable. A width of 18 ft. gives a space of 5 ft. each side, clear of the ties, to include the ditch; and it is about the least room that will allow for taking out ties in renewals, after assuming that the bank slopes well away from the ditch and that the track will be raised above sub-grade when ballasted. Under less favorable conditions, as when, for instance, the cut is deep and long and much water is to be carried in the ditch, or when the cut is through wet material or material of the nature of clay, 18 ft. is entirely too narrow. As far as I am able to discover, the largest practice with trackmen, wherever the ballast does not exceed 12 ins. in depth under the ties, seems to be to maintain ditches at a distance of 7 ft. from the rail to the foot of slope at the back side of the ditch. This measurement gives a roadbed about 19 ft. wide; and right here it should be explained that the roadbed constructed or maintained by trackmen does not always measure fully up to the blue-print drawings in the chief engineer's office. In order to treat the subject comprehensively one should not fail to investigate the least width of roadbed upon which good track can be maintained, because it is upon roads of small earning capacity that questions of this kind must receive the most studious consideration. On roads with large earnings at disposal the question of the most economical width of roadbed largely disappears, and a width may be selected which is known to be sufficient to afford desirable conditions. I have therefore outlined, in a general way, what I consider to be typical conditions or situations to be met in ditching and the least width of roadbed which may apply to each case.

In a dry gravel cut there is seldom need for a ditch, because ordinary rainfall does not, on such ground, run off on the surface. As, however, the material ought to be removed far enough back from the ends of the ties to make room for taking them out without too much digging during renewals, or without having to raise the rail, it is well to slope it away gradually somewhat lower than the bottoms of the ties, as far as there is room. This will provide for those extraordinary rainfalls when water comes in quantities faster than it can soak away, and also for winter, when snow melts on frozen ground. Six inches is far enough to go below the level of the bottoms of the ties in this instance. Of course it improves appearances to make the ditch deeper, but as the whole foundation is porous this is a case where the requirements for ditches under almost all other conditions do not arise. Engraving *A*, Fig. 3, is an illustration of this ditch.

In all other cases the ditch ought to fulfill the following requirements: it ought to carry the water away below the level of the bottom line of the ballast, because all ballast except common dirt is porous, and if the ditch be not lower than the bottom line of the ballast the latter will be soaked with water whenever there is any in the ditch; the ditch should also have at least a slight grade, which can be maintained, even on level ground, by

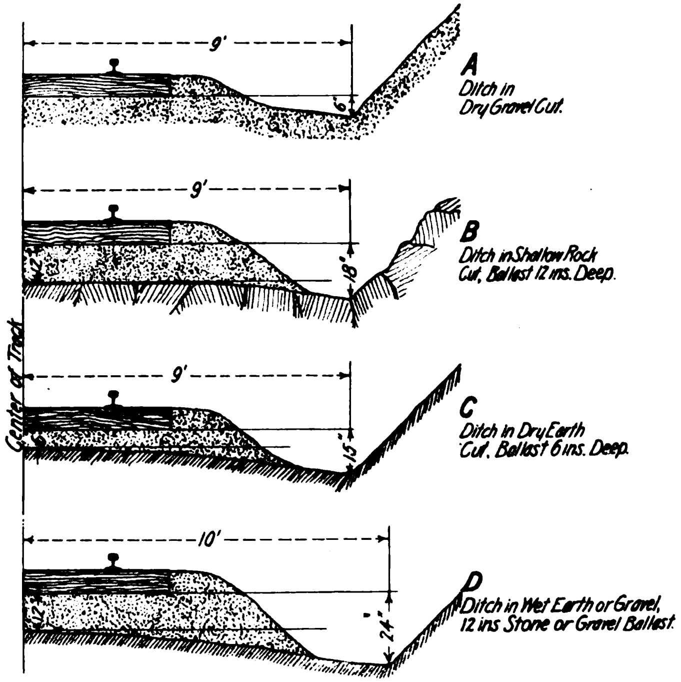


Fig. 3.—Half Sections of Roadbed and Ballast.

making the ditch deeper at one end than at the other. In such a ditch the water has a chance to run off; whereas, in a level ditch water is liable to be dammed and held to soak through the roadbed, causing the track to heave in winter time and require shimming.

In rock cuts the bottom of the ditch need not be more than 6 ins. below sub-grade unless the quantity of water to be carried off cannot be accommodated by such shallow depth. In shallow rock cuts the toe-to-toe width of roadbed should, for convenience of tie renewals, be at least 18 ft. Engraving *B*, Fig. 3, shows the amount of ditch room available in such a cut where 12 ins. of ballast is used. In deep rock cuts the expense of excavation becomes a paramount consideration, and in such places 16 ft. is a very common width of roadbed.

In a dry cut the only water to be carried out of it is that which falls between the slopes, and under ordinary conditions a ditch 9 ins. deep below sub-grade will answer. In such a cut the quantity of ballast required does not exceed that required for fills. For a depth of ballast not exceeding 6 ins. below the ties a toe-to-toe width of 18 ft. will answer. Engraving *C*, Fig. 3, shows such a roadbed for dry earth cuts, the term "earth" in this connection meaning common loam or sand in distinction from gravel and unmixed clay. If, however, there is more or less water in the cut coming from springs which flow out of its slopes the ballast and the ditch should both be deeper than in the case just referred to, and the cut must therefore be wider. The ditch should be at least a foot lower than sub-grade and the ballast a foot deep above sub-grade. Twenty feet between the slopes, toe to toe, will give ditch room for single track, as shown by Engraving *D*, Fig. 3. Where springs come up through the roadbed there is usually much difficulty in keeping the ballast dry and the track to surface. The only remedy lies in widening out the cut to make room for a ditch which slopes away from the track gradually, and in putting in a good depth of ballast,

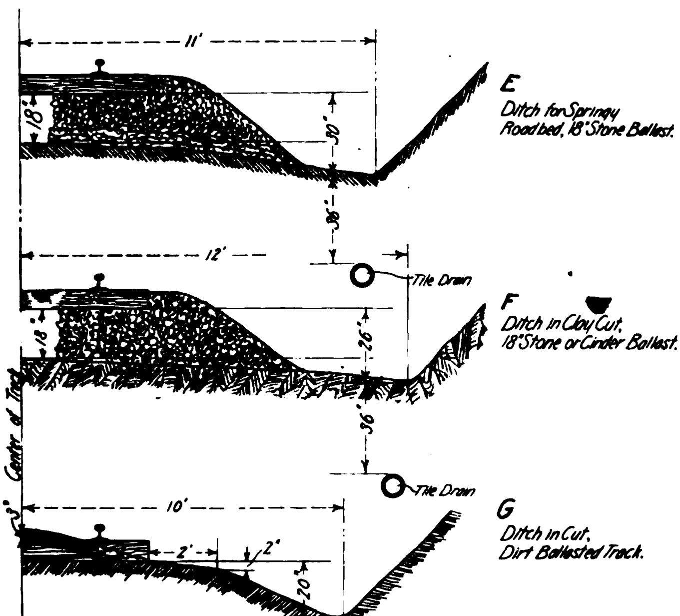


Fig. 4.—Half Sections of Roadbed and Ballast.

the bottom course of which is rather coarse rock. About 18 ins. of ballast should be used and the cut should be at least 22 ft. wide at sub-grade, as shown in Fig 4, Engraving *E*.

In a clay cut a deep ditch cannot be maintained, for the reason that when the top of the roadbed becomes wet it will slide laterally, under the weight and shock of passing trains, and fill the ditch, if there be much of a slope toward the same. Mistakes are often made in cases of this kind. When the track is found to be settling and the ditch filling up, in such cuts, some trackmen will deepen the ditch accordingly, making allowance in depth for the plastic clay which they evidently think cannot be kept out. Such treatment only makes matters worse, for it weakens the roadbed by taking away its lateral support, and the material under the track will keep pushing into the ditch and the track will continue to settle. The proper thing to do is to widen out the cut to make room for a roadbed which slopes so gradually that it will not slide out—a flat roadbed, comparatively speak-

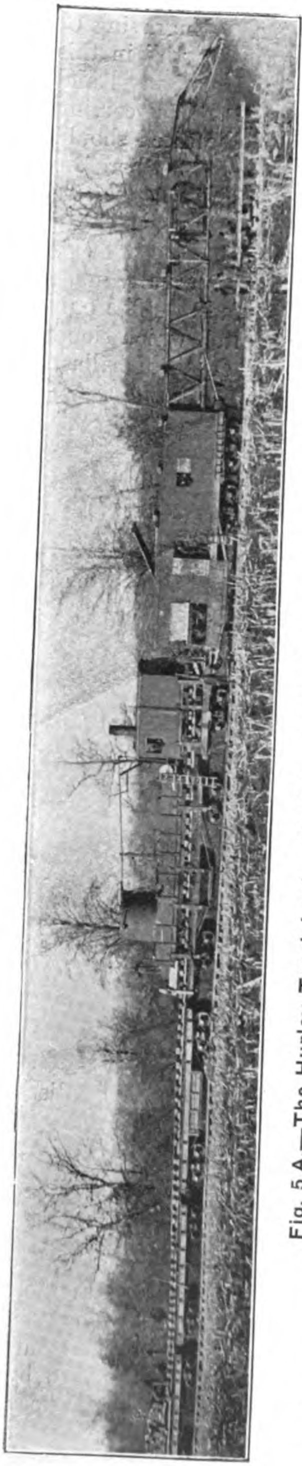


Fig. 5 A.—The Hurley Track-Laying Machine, in Use on the Bessemer & Lake Erie R. R.

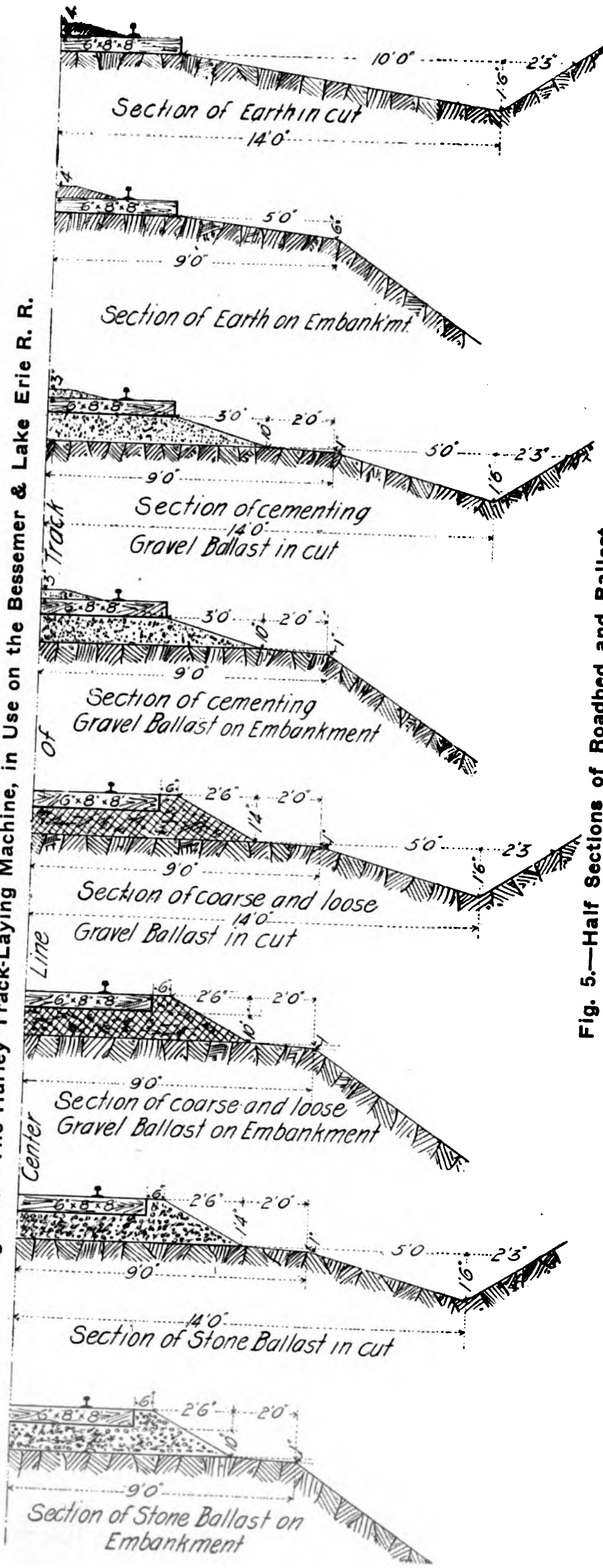


Fig. 5.—Half Sections of Roadbed and Ballast.

ing, or one which crowns just enough to drain the water into a broad, shallow ditch next to the slope. In clay cuts ditches should never be formed by shouldering the roadbed. Eight inches below sub-grade provides depth sufficient to carry off the water, and the toe of the slope,—that is the far side of the ditch—should be at least 12 ft. from the center of the track. Engraving *F,* Fig. 4, illustrates this arrangement. The depth and nature of the ballast required are discussed in §12.

One more case invites consideration, namely the ditch for dirt-ballasted track. Of course it goes without saying that such is not suitable ballast where there are springs under the track, but a ditch can be made which can drain the track of water coming from the side. A cut of 20 ft. width, for single track, will allow a shoulder about 2 ft. wide outside the tie ends, sloping away 2 ins., and a ditch about 18 ins. deeper, at an ordinary slope of 8 to 3, as illustrated by Engraving *G,* Fig. 4.

The foregoing seven conditions cover perhaps all the general problems which arise in ditch construction, or those which call for different methods of treatment. The depth of ballast needed and depth of ditch should, after the nature of the cut is known, determine largely the width of cut, and not the width of cut the depth of ballast and depth and slope of ditch. Bearing in mind that the variety of roadbed and ditch measurements here presented is due to a close study of conditions, to ascertain what might be considered the least measurements applicable to conditions which obtain in common practice, it may be explained that it is not usual to find so many standards in practice with one company. It is more frequently the case that a single set of measurements, large enough to answer the requirements of the worst supposable conditions, is made standard. The roadbed sections shown in Fig. 5 are an illustration of such practice, there being but one width (18 ft.) for roadbed at sub-grade, both on embankments and in cuts, and but one toe-to-toe width of roadbed in cuts (28 ft.). These sections represent liberal roadbed measurements in cuts. The standards of the Illinois Central R. R., even though more liberal, are yet quite similar, the only differences being in width of roadbed at sub-grade, which is 20 ft. both for embankments and in cuts, making the width of ditch 6 ft. 3 ins. instead of 7 ft. 3 ins., as shown in the illustrations. The gravel ballast is shouldered out 18 ins. beyond the ends of the ties, instead of 6 ins., and stone ballast is shouldered out to 12 ins., instead of 6 ins.

In excavating ditches the angular form of the standard cross section at the meeting lines of slopes (drawn that way for convenience of indicating dimensions clearly), should not be followed. The various slopes forming the outlines of the ditch should meet by curved surfaces; as, for instance, the bottom of a V-shaped ditch should be rounded out and not brought to a sharp corner. The rounded corner is the shape which results from the forces of nature and it applies to the edges of embankment slopes and the top edges of slopes in cuts as well as to ditches.

Where it can be done the ditch should be given grade sufficient to carry off the water with some rapidity; a fall of at least 4 ins. per 100 ft. is desirable, and 6 ins. per 100 ft. is a common specification. The dimensions of ditches shown on the standard drawings of railroads are usually supposed to represent the cross section of the ditch at the highest point. In case it becomes necessary to deepen the ditch to obtain a grade, as on level ground, the standard dimensions must then be exceeded. The standards of the Louisville & Nashville R. R., are different in this respect. On this road the ditches are made with a flat bottom and the width of roadbed between ditches is 16 ft. The grade of the bottom of the ditch must not be less than 6 ins. per 100 ft., wherever such is practicable. In summit cuts the ditches are 3 ins. deep at the summit and in level cuts they are 3 ins. deep at the middle of the cut, increasing to the standard depth of 12 ins. toward the ends. In cuts where the grades are steeper than ½ per cent the grade of the ditch is made parallel with the grade of the track and 12 ins. deep. This practice seems proper, because at a summit in a cut or at the middle of a level cut from which the ditches slope either way, there should be but little water in the ditches, and in long level cuts they must be made shallow at this point in order to avoid running too deep in obtaining the necessary grade. Deep ditches in soft material are objectionable, as already explained, and in any material the deepening of ditches in deep cuts requires the removal of large quantities of material in making the slopes.

Ditches should be made regular in width, and smooth, so that puddles of water will not stand in them, to afford a source for seepage. If, owing to the shape of the cut or for any other reason, a ditch cannot be made regular in width it is well to make the track side of it straight and parallel with the rails. Where there is an embankment or fill adjoining a cut the offtake ditch or ditches should be diverted from the made ground and carried around on solid material. Neglect of such precautions has been the cause of many a bad washout during times of excessive rainfall or sudden thawing. The track ditch may be turned into the surface ditch and the channel formed by the two combined may be run to the nearest culvert or stream. If the ditch must be carried over or near made ground the embankment may be protected against scour by paving or riprapping. Another arrangement having the same purpose in view is to conduct the water from the end of the cut through a line of large drain tile or sewer pipe laid to a good grade. Tile as large as 15 ins. in diameter has been used in cases of this kind. In long side-hill cuts it is seldom necessary to carry the water the entire length of the cut, as the ditch may be turned under the track at intervals, through box drains or culverts. In through cuts the ditches should be of the same depth on both sides of the track, on curves as well as tangents.

Tile Drains.—Valuable assistance to the drainage can be obtained by laying drains of farm tile under the ditches (Engravings *E* and *F*, Fig. 4). Especially is this the case in wet cuts or in cuts where there is not room for a ditch of proper width and depth, and in cuts where there is trouble in keeping the ditch clear of sliding material. The utility of tile drains or "blind ditches" has long been demonstrated by farmers, and the use of tile in railway work is increasing. The ditch serves to carry off water when it comes in quantities, as during storms or thawing weather, and seepage into the tile drain prevents water from standing in the ditch at ordinary times and also drains out the roadbed to the level of the tile. Where under drains are used the ditches may be made shallower than otherwise, and in some kinds of material this is a considerable advantage. To put the tile below frost, or at least below the action of hard frost, it is laid 2½ to 4 ft. deep. Water running continually in a tile drain will compromise the action of frost to some extent. In tile-draining a through cut it is usual to lay drains under both ditches. If practicable the drain should have some fall, 3 ins. per 100 ft. or ⅓ in. per rod, being desirable. Tile is made in 1-ft. and 2-ft. lengths, but the 1-ft. lengths are preferable for the sizes up to 12 ins. in diameter. Round tile at least 5 ins. in diameter is preferred for railroad service. It is frequently used in sizes up to 8 ins. in diameter, where the quantity of water so requires, and 6-in. tile is commonly in use. In very long cuts it may be necessary to increase the size of the tile toward the end of the cut or to lay two lines of tile in the same trench, but resort to either plan is unusual in practice. Glazed tile is stronger than the unglazed article for the same thickness, but if the unglazed tile is properly burned it is considered quite strong enough for practical purposes, and just as durable. Water enters a tile drain through the joints. Water under pressure will percolate through the wall of the tile in some quantity, but in ordinary drainage all that gets through in this manner amounts to but very little, and cuts no figure in drainage. Unglazed tile will absorb water until the pores become filled, but without some force behind it there is but little tendency to pass through.

Experts in tile drainage work have special tools for digging the trench and laying the tile. For excavating the top portion and body of the trench a long and narrow shovel or post-hole spade (Engraving *B*, Fig. 6) is used. The blade measures 5½ ins. wide at the step, 6 ins. at the cutting edge and is 18 or 20 ins. long. For sticky soil the skeleton ditching spade shown as Engraving *A*, with a blade 18 or 20 ins. long and 6½ ins. wide, is preferred. For taking out the bottom spading a round-pointed spade (Engraving *D*) with a blade 18 ins. to 22 ins. long, 5½ ins. wide at the step and about 4½ ins. wide at the cutting edge, is used for ordinary soil, and for sticky soil the round-pointed skeleton spade shown as Engraving *C*, with a blade 18 or 20 ins. long and 4½ ins. wide, is used. These tools enable the excavation of a narrow trench but little wider than the tile, if desired, thus

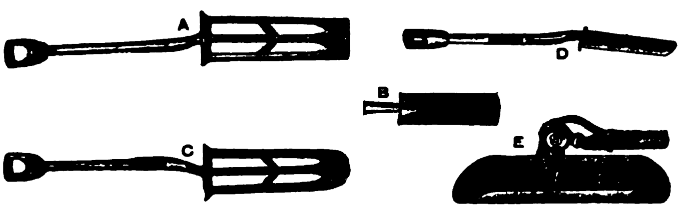


Fig. 6.—Tools for Tile Drainage.

saving something in material handled and expediting the work. To clean up the bottom of the trench for laying the tile a drain cleaner (Engraving *E*), consisting of a scoop with a long handle, arranged to draw toward the user, is employed. The blade is made of shovel steel, 15 ins. long and 4 to 6 ins. wide, according to the size of the tile. The handle can be adjusted to any angle convenient to the user, by raising the spring, and when the spring is in position the blade is locked against rocking. As a guide for dressing the bottom of the trench to a uniform grade it is customary to set grade stakes at intervals of about 30 ft. alongside the line of the trench, using an engineer's level. A ditch line is then tightly stretched from stake to stake, to the grade for the tile, and after the trench has been nearly completed in depth measurements are taken from this line for dressing up the bottom. A measuring instrument commonly used consists of a vertical staff graduated to feet and inches, with a horizontal sliding arm made fast by means of a thumb-screw. The arm carries a spirit level and is long enough (about 2 ft.) to reach the ditch line when the staff is stood in the trench. In railroad work where the track is in good surface the rail might be used as a reference for the grade of the trench. In order to have the trench in smooth condition for laying the tile, the workmen dress it to grade without stepping on the bottom. The sections of tile are laid to place with a hook on the end of a long handle. For laying tile through quicksand a sheet iron box, open top, bottom and rear, and commonly known as a "coffin," is used. This box, and the use of the same are described in §196, in Supplementary Notes.

The tile should be laid to a straight line and uniform grade, with the joints fitting closely. Some use a pole of round or square timber somewhat smaller than the inside diameter of the tile, to keep the tile properly lined up while it is being tamped and covered over. Each advance section of tile is strung upon the pole as it is pulled ahead one section at a time, the rear end of the pole remaining continually within the covered tile. When laying tile on very soft ground the precaution is sometimes taken to lay a narrow board in the bottom of the trench, to prevent displacement of the tile sections. When filling in the trench with loose material it is the practice with some to cover the tiling with inverted sods, moss, slough grass, hay, straw or some such material, to exclude fine particles of filling which might be washed into the tile through the joints. As a means of aiding seepage toward the drain some recommend filling the trench with coarse gravel or cinders, but not with loam or sand; while others of long experience claim that the water will readily find its way into the drain through any material, however compact, and for filling in the trench such men prefer to use only the material excavated, without straw or other screening material. The bottom spading is considered the best material to place directly upon and surrounding the sides of the tile. Stiff blue clay is considered excellent material for covering over tile. In cuts with wet slopes, where the bank is liable to slide, it is sometimes the practice to cut ditches diagonally down the slope to ease the grade for the running water. A better plan, where there is tile sub-drainage for the ditch, is to conduct the water down the slope through covered diagonal branch drains leading into the main line of tiling. A pile of loose stones or wire netting should be placed over the outlet of a tile drain to keep out muskrats and other small animals. To lay drain tile properly requires experience, and some railway companies find it cheaper and productive of better results to employ experts who have worked among the farmers, to do this work. Twenty-three cents per rod for the work of digging the trenches ($3\frac{1}{2}$ ft. deep) and laying the tile is a price that has been paid by the Chicago, Burlington & Quincy Ry. to contractors. Mr. Alexander Birss, Prairie, Wash., who was formerly engaged for a great many years as a tile-drainage contractor, in Iowa, has kindly favored me with some interesting information on tile drains and the work of laying them, which may be found in §196, Supplementary Notes, in the back part of this book.

As a substitute for tiling a continuous bundle of poles, trimmed of their branches and placed butts and tops, is sometimes laid in the bottom of the trench and covered over. Blind ditching may also be done by partly filling the trench with broken stones, preferably placing a plank in the bottom of the trench. A form of blind ditch much used by farmers in the eastern states is laid with flat field stones as a bottom paving, and on top of these, flat stones are stood edgewise leaning toward the middle of the trench from both sides, to form an inverted V-shaped opening 2 or 3 ins. wide at the bottom. Over these stones other stones are thrown in loosely and covered with the soil.

The most desirable way to ditch yards is by sub-drainage with tiling or, if the area to be covered is extensive, with branch drains of tile feeding into sewer pipe mains. Catch basins at points where water is liable to collect are desirable, as they prevent the formation of puddles of water between the tracks, which get covered with ice during freezing weather. The work of switching may be considerably expedited by maintaining the footing in good condition in all kinds of weather.

Ditch Paving.—The paving of ditches with cobble stones is practiced to some extent. Where coarse gravel is on hand the paving material is easily obtained and the work of laying it is not very expensive. Paved ditches retain their shape better than unpaved ones, because they are flushed by heavy rains, and if filled by sliding material or sediment washed down there is a good bed to shovel upon when cleaning out the ditch. To improve the appearance of ditches in the vicinity of stations the paving is sometimes whitewashed. Whitewash will keep the paving clear of grass, and if salt is mixed with the lime the whitewash will adhere better to the stones. Concrete paving or lining is also applied to ditches on a number of roads. Brick, cement and asphalt are materials used for paving some of the ditches on the Pennsylvania R. R. In ditches through soft material on steep grades some kind of paving is necessary to prevent gullying in time of hard rain storms. On some roads old ties have been used to good advantage in ditches where such protection is necessary.

Retaining Walls for Ditches.—Various means, some of which are mentioned in § 160, are resorted to for maintaining open ditches along sliding banks. A common method of securing the foot of a sliding bank is to build a thick masonry retaining wall and lay tile drains at the back side, under back filling of coarse gravel or broken stone. Such walls are usually built to a heavy batter, like ¼ to 1, and topped out with heavy coping stones. The bank is then sloped from the top of the wall, reducing the general slope and lessening the tendency to slide. In order to make sure provision for drainage, weep holes through the wall with a ditch in front of it are recommended. An interesting piece of work that may properly be referred to in the present connection is a concrete slope facing constructed at Chestnut street, St. Paul, Minn., to protect the tracks of the Chicago, Milwaukee & St. Paul Ry. from falling rock and other material. At this point there is a side-hill cut through soft sandstone for several hundred feet, the sandstone being overlaid with a limestone ledge and the latter surmounted by a glacial drift formation of sand, gravel, boulders, etc. The bank rests at a slope of about 1 horizontal to 2 vertical, and a cut-stone masonry retaining wall had been built along part of the distance to support the limestone ledge, which was constantly being undermined by the disintegration of the sandstone. As a means of cheapening the construction, a concrete facing wall, with brick pilasters at intervals to support the limestone ledge, was substituted for the remainder of the distance, it being assumed that if the sandstone could be protected against rain and frost its stability would be secured. The foundation for the facing wall and pilasters was put into the sandstone 4 ft. below rail level. The facing is 256 ft. long and 56 ft. high, and was built up by depositing concrete behind a wooden form built from the foot of the slope by stages and supported on bolts anchored to the standstone. These bolts were jointed about the middle of their length, and after the concrete had hardened the outer half of the bolt was withdrawn, the hole filled with cement mortar, the concrete facing thus remaining bolted to the sandstone bluff. The average thickness of the concrete facing below the ledge is 2 ft. 5 ins., and above the ledge, 3 ft. 2 ins.

5. Culverts.—The drainage of roadbed comprises ditches and culverts, the purpose of the latter being to convey ditch water or small streams underneath the track or to permit the escape of rain water, melted snow or springs draining toward an embankment. To be serviceable under all conditions a culvert must answer the requirements of size, and be secure in foundation and end construction against washing out. Respecting the first essential, engineers when laying out culverts should exhaust every resource available for estimating the quantity of water liable to flow along the streams crossed, especially those which are found dry at times. Where opportunities are at hand, as in settled districts or where roads or railways traverse the country, the most satisfactory way to estimate the size of culvert openings is by observation of the volume of flow during high water, either at the time or by high-water marks. To find the latter, observation may be made of existing openings on the stream or by examination of the banks, preferably where the stream is contracted; or by inquiry of parties familiar with the locality. Along with every party doing the preliminary surveying for a railroad there should be some man experienced in exploring or "cruising," who should scour the country surrounding for such information regarding the rainfall and the streams as will be of benefit to the company in the proper construction of its bridges and culverts. In placing culverts on an old road the determination of the sizes of the openings is less problematical, because exact records of high water should then be obtainable. In constructing railways in this country, and particularly in the West, it is extensively the practice to bridge the water courses with timber trestles, so that the construction of permanent works at the drainage openings is usually postponed until the wooden structures need renewing. This gives a period of some eight or ten years, during which time it is customary for both the bridge and track departments to keep record of high water at the various openings, as reported by the bridge inspectors and the section foremen. In a large proportion of the cases, therefore, there need be no uncertainty regarding the capacity of culvert openings. The contingency does sometimes arise, however, that the capacity of culvert openings must be determined upon where reliable information concerning the streams cannot be had. Under such a circumstance the engineer is compelled to resort to some basis for estimating the maximum rate of discharge through each opening. The investigation of such problems proceeds so largely upon matters of judgment that many are disposed to regard the accepted methods of calculation as in large degree conjectural, or as processes more or less entangled with guesswork. While it is true that much of the data made use of in such cases are necessarily assumed, or even guessed at, it is also true that some determination is compulsory, and guessing by method is certainly preferable to guessing at random. The amount of confidence to be reposed in calculations of this kind depends, of course, upon the experience and observing capacity of the engineer in charge.

Calculation of Maximum Flow.—Where reliable information cannot be obtained regarding the maximum flow of the streams the size of opening or, what leads to the same end, the maximum flow through the opening, is determined by some empirical rule or method of calculation. One of the simplest rules is to base the unit of opening area upon acreage. For instance, it is commonly the practice to allow a square foot of culvert opening for some certain number of acres drained, the relation of drainage area to the unit size of opening being ascertained from experience with the topographical conditions and rainfall of the particular section of country. To give one or two illustrations of such practice, the Chicago, Rock Island & Pacific Ry. allows for drainage, in Nebraska, Kansas and eastern Colorado, as follows, a single line of cast iron pipe being referred to each case: 16-in. pipe for 20 to 40 acres; 20-in. pipe for 30 to 60 acres; 24-in. pipe for 45 to 90 acres; 30-in. pipe for 70 to 140 acres; 36-in. pipe for 110 to 220 acres; 48-in. pipe for 180 to 360 acres. These allowances are based upon 14.3 to 28.6 acres per square foot of opening, or an average of about 21½ acres per square foot of opening. The wide latitude left to the discretion of the party in charge of construction enables him to take into account the variability of the topographical features, such as the slope of the ground, the state of the soil (whether cultivated or not), and the shape of the drainage basin; as, other features being similar, water draining out of a circular valley will flow off more rapidly than from a long, narrow valley of the same area. The rules in force on the New York Central & Hudson River R. R. when reliable records of the flow of water to be taken care of at any new culvert cannot be had, are similar. For 5 acres of steep land or 10 acres of flat land, 10-in. pipe is used; 12-in. pipe for 10 acres; 16-in. pipe for 20 acres, and so on up to 36-in. pipe for 110 acres. Compared with rules in force on some other roads for small culverts these openings seem small. On the Missouri Pacific Ry. it has been the practice to allow one square foot of opening to drain four acres of steep or mountainous land or six acres of flat or rolling land.

Another way of determining the area of culvert openings is by the use of an empirical formula, in which the factors are the drainage area and a variable coefficient to suit the conditions of the locality. The best known formula of this class, or the one which has been most extensively used in American railway practice, is the Myers formula, proposed many years ago by Mr. E. T. D. Myers, since then president of the Richmond, Fredericksburg & Potomac R. R., by which

$$\textit{Area culvert opening in sq. ft.} = C \times \sqrt{(\textit{Drainage area in acres})}$$

The values usually given to C are: for flat or slightly rolling ground, 1; for hilly ground, about 1.5; and for mountainous and rocky ground, 4. The important respect in which this formula differs from the foregoing rules is that the size of opening varies as the square root of the drainage area instead of by a straight proportion; which would make it appear that the so-called "rules" require an opening too large for the larger drainage areas. Such is probably the case, for it is well established that the rate of flood discharge from a large area compared with the rate from a small area for the same rainfall and same duration, is not as great as the ratio of the two catchment areas. In the Talbot formula the size of opening is made to vary as the fourth root of the cube of the drainage area, thus:

$$\textit{Area culvert opening in sq. ft.} = C \times \sqrt[4]{(\textit{Drainage area in acres})^3}$$

In this formula the coefficient C takes a value varying from $\frac{2}{3}$ to 1 for steep and rocky ground; and $\frac{1}{3}$ for rolling agricultural country subject to floods at times when snow melts, where the valley is three or four times as long as it is wide; if the valley is longer in proportion to width the value of C is decreased still further. In districts where snow does not accumulate, C is taken at $\frac{1}{5}$ or $\frac{1}{6}$, or even less, for oblong valleys. In the case of either of these two formulas it is quite apparent that experience and good judgment are essential to a proper choice of coefficients. In any case of uncertainty in this respect the opening should be given the benefit of the doubt.

The most thorough way of getting at the proper size of waterway, where authentic report concerning the maximum flow of the stream is not procurable, is by a survey of the drainage basin and the various conditions which affect the situation. Such work is sometimes undertaken for openings of considerable importance. On the Atchison, Topeka & Santa Fe Ry. it is the practice when constructing new culverts to send an engineering party around the watershed and have a rough survey made of the drainage basin. Although there are numerous formulas which may be applied to some of the elements concerned in an investigation of this kind, I think I can do no better than follow the sense of a paper on this subject presented before the Institution of Civil Engineers by Mr. George Chamier, in 1898. The elements which must be taken into account as a basis for calculating the maximum discharge are (1) drainage area, (2) rainfall, (3) amount of surface discharge and (4) the diminution in proportionate flood discharge due to area. Regarding the drainage area the form and greatest length of the catchment basin are all important, as well as the extent, for upon these features depends the time required for the flood water to reach the outlet from all parts of the drainage basin. Thus, with surrounding ridges of the same elevation, in either case, the discharge of flood water from a circular basin takes place more rapidly than from an oblong basin, for the reason that the distances traversed by the various streams are shorter and the declivities greater. The general slope of the ground over the catchment area and the outlines of the valley traversed by the main stream are also important, as affecting the velocities of the streams. The estimation of the time required for the flood water to reach the outlet from the farthest point of the basin calls, of course, for the judgment of the investigator. The velocity of the water increases as it collects into well defined channels. The time required for rain water to flow off the surface into the brooks is rather conjectural, in any case, but the rate of flow over grassy surface may be taken at ½ mile per hour for moderate slopes, and 1 mile per hour for steep side-hill. Under average conditions the velocities of streams range from 2 to 4 miles per hour, but in mountain torrents and rapid rivers much higher velocities have to be considered. The velocity in any case can be ascertained approximately from the dimensions and inclination of the channel, with some assumption as to the probable volume of flow at times of flood. The reliability of all such estimates depends, of course, upon the experience and judgment of the calculator.

As to rainfall it is desired to know the maximum downpour during a period corresponding to the size of the drainage area—that is, for such a time as is required for the flood water to reach the outlet from the farthest extremities of the basin. The maximum rate of precipitation occurs only during short periods, of an hour, or a few hours, at most, so that, for the smaller drainage areas, for which the duration of fall to be considered is necessarily short, it would be incorrect to estimate the maximum fall in proportion to the maximum daily fall. Thus, for instance, it is not uncommonly the case that 25 per cent of the maximum daily fall is registered in an hour. In order to get at flood discharge it is, of course, essential to have some record of the rainfall for the section of country, and in order to anticipate the greatest rainfall for short periods with a reasonable degree of assurance it is necessary to have approximate data as to the diminution of the rate of fall with the duration.

As to surface discharge, it is known that, owing to absorption of the soil, evaporation and percolation into subterranean passages, only a portion of the rainfall need be taken into account. The ratio of the water which flows off the surface (and finds its way into streams) to the total amount of rainfall is known as the "coefficient of surface discharge." For countries where heavy rains are liable to occur when the ground is frozen this coefficient is usually assumed at ⅔, while for rocky mountain slopes without fissures, very steep ground, or paved streets the assumed value may exceed 0.80. As a general rule the coefficient of surface discharge is taken at some value between ⅓ and ⅔. Mr. Chamier's estimates are as follows: For flat country, sandy soil or cultivated land the coeff. disch. is taken at 0.25 to 0.35; for meadows and gentle declivities, absorbent ground, 0.35 to 0.45; for wooded slopes and compact or stony ground, 0.45 to 0.55; for mountainous and rocky country or non-absorbent surfaces, 0.55 to 0.65. It is clear, of course, that the maximum ratio of surface discharge to rainfall does not obtain until the ground has become thoroughly saturated.

Aside from the diminution of the discharge due to the above causes there is also a diminution due to causes which act upon the water after it has collected into streams, such as evaporation, which in hot climates is great; and absorption by overflowed lands or by irrigation; or percolation through the banks. In limestone countries streams of considerable size sometimes entirely disappear into underground channels. And then the flow of some streams is impeded, and the rate of discharge diminished, by obstructions in the form of dams or accumulations of flood debris, while lakes and swamps are well known regulators of flood discharge. For average cases Mr. Chamier gives $(\sqrt[4]{M^3}) \div M$ as the ratio of decrease of flood discharge due to area, where M denotes the area of the drainage basin in square miles. Observation of, and experience with, the conditions in particular localities would quite likely find different powers of M suitable to the various conditions obtaining. Thus it appears that in determining upon the data for the solution of the problem the judgment of the investigator is called into service at every step.

Having considered the various elements of the problem in some detail the formula for flood discharge at the outlet follows by the simplest logical process, being

$$Q = A \times R \times C,$$

where Q denotes the maximum discharge in cubic feet per second; A, the number of acres; R, the average rate of greatest rainfall anticipated, in inches per hour, for such duration as will bring flood water to the outlet from the most distant point of the drainage basin; and C, the coefficient of surface discharge. If the drainage area exceeds 1 square mile, the formula must include the factor for diminution of discharge according to area, and it then becomes

$$Q = A \times R \times C \times (\sqrt[4]{M^3}) \div M;$$

or, substituting for A in terms of square miles, the factor $(A \div M)$ disappears and we have

$$Q = 640 \times R \times C \times \sqrt[4]{M^3}$$

One inch of rainfall per hour over a surface of 1 acre is at the rate of 1 cu. ft. of water falling per second, which is the rate of discharge, supposing all the water to flow off. Having ascertained the maximum discharge to be anticipated at the outlet, the area of the opening will depend, of course, upon the velocity of flow, which is frequently assumed at 10 ft. per second. In the case of mountain torrents and rapid streams, where the velocity exceeds this figure, the error is on the safe side; and if the natural velocity is less than the figure assumed the amount of head necessary to produce a velocity equivalent to the difference is but small, and if the foundation of the structure is secure against scour there need be no concern if discharge occurs under moderate pressure.

Before dismissing the subject of calculating culvert openings it should be borne in mind that rainfall is not always the only source of flood water to be taken into account. In regions where snow accumulates or falls to considerable depth the highest floods may occur when the snow melts, as then the flow of water may be due to heavy rainfall and melting snow combined. Thus, for instance, in some parts of the State of Washington, on the western slope of the Cascade mountains, the most troublesome freshets occur late in the fall, when heavy rains, accompanied by a "Chinook" wind, fall upon heavy accumulations of October snow. To know the extent to which melting snow contributes to the volume of flood water requires special knowledge of the climatic conditions obtaining in particular sections of country, and the matter is so important that it should never be lost sight of in fixing upon culvert areas. In building a road through a wooded country waterways should be made about double the size found necessary for use at the time they are built, so as to allow for the increased rate of drainage after forests are cleared away, swamps drained, etc.

Open Culverts.—Where the track crosses small rapid streams which wash down large quantities of drift, and the track is close to the bed of the stream, it is sometimes necessary to construct an open culvert, in order that the opening may be accessible for cleaning out when it becomes filled or obstructed. Formerly it was much the practice to construct such culverts by merely laying two stringers across walls of masonry or heavy sills, to carry the rails. In some sections such is known as a "beam" culvert. Such openings in the track are not to be advised, as in the case of a derailed car or truck running into the same there is certainty of wreck to the train. Where an open culvert is unavoidable a standard bridge floor should be built over the opening. When it becomes necessary to clean out such an opening it is an easy matter to remove some of the ties or spread them apart. Another occasion for shallow openings under the track arises in irrigation districts, where the right of way is crossed by ditches or canals in which the water level is but slightly lower than the track. On the El Paso division of the Southern Pacific road trough stringers have been used for the support of the track rails over irrigation ditches. This stringer is formed by riveting two 12-in. channels (placed back to back) to a third channel of same width placed open side downward between them. The rail rests upon 4x12x12-in. creosoted blocks placed in the trough, the depth of which is such as to bring the top of rail flush with the top of the stringer. The fastening for the rail consists of clips, with bolts passing through block and bottom channel. For 15-ft. spans the sides of the trough are formed of channels each weighing 50 lbs. per foot, and for 12-ft. spans the channels weigh 30 lbs. per foot; the bottom channel used in either case weighs 30 lbs. per foot. At the ends the stringers are anchor-bolted to 12x12-in. caps with bearing plates 1 in. thick between the two. On the Pacific system of the same road a similar method of support is employed in crossing irrigation ditches, the stringer supporting each rail in this case consisting of two pieces of T-rail 5 ft. long, spaced just far enough apart to permit the flange of the track rail to lie in the opening between their webs. The flange of the track rail fits closely under the heads of the two stringer rails and is supported upon bolts passing through the webs of the stringer rails at intervals of 18 ins. In some places there are as many as three consecutive spans of these T-rail stringers.

Wooden Box Drains.—Box drains made of plank of durable lumber, like cedar, are admissible for small cross drains where the depth under the track is not sufficient for masonry or pipe culverts. Such a box may be made by spiking together four 3x12-in. planks, standing the side planks within the edges of the bottom and cover planks. It should be made 15 or 16 ft. long for single track roadbed, or long enough to reach to the ditch line. The ends may be sloped to conform to the side of the ditch or slope of the shoulder. When placed between the ties such boxes are usually left open on top, the sides being held apart by flat strips nailed across the top edges. If there is much fall in the water directly upon leaving the box the ground should be paved with stones for a safe distance, or, if the quantity of water amounts to nothing more than a trickling stream, as from a permanent spring, it may be conducted away by a V-shaped trough made by nailing together two 1x6-in. boards. Where one box of this kind is not large enough to carry all the water which may come at times, and the track is not high enough above the stream to admit of a deeper closed culvert, a partitioned box may be used, spacing the partition planks, say, 12 or 15 ins. apart, the number of partitions made depending upon the width of opening desired. In this case the bottom and cover planks should be spiked on crosswise the box. All such small passageways should be at least 6 ins. below the bottoms of the ties. The use of a box drain is superior to the practice of leading small streams or springs under the track by an open ditch and placing the track upon stringers thrown across the ditch. These stringers will continually settle and give trouble. For unimportant side-tracks such a makeshift may answer well enough, using ordinary 8-ft. ties for stringers. To prevent the track ties from slewing out of their proper positions they may be drift-bolted to the stringers, or cleats may be nailed to the stringers between the ties, or a board may be laid outside each rail, parallel to the same, and nailed to the ties. A substitute for a box drain is sometimes made by building a walled trench about 12 ins. wide in the clear and paved on the bottom. The trench opening comes in the space between two ties, and, being open, can readily be cleaned out when clogged with mud or ice. To prevent people from stepping into such openings in the dark they should be provided with a removable plank cover.

Along side-hill cuts it is a good plan to carry springs (where there are but a few of them some distance apart) directly across the track at the point where each comes out, instead of allowing two or more to flow together before leading them across. In long through cuts where the track is curved and water runs continually, it should be carried under the track from the ditch on the outside of the curve to the ditch on the inside of the curve, at frequent intervals, so that it may run against the bank; if it was to run altogether in the ditch on the outside of the curve it might cut into the roadbed or into the ballast on the shoulder.

Timber Culverts.—In districts where timber has been plentiful it has been used in culverts a great deal, especially where difficulties have stood in the way of delivering permanent materials at the site of the culvert in time for the graders. In timber countries such culverts can be quickly and cheaply built, and under certain circumstances such construction is undoubtedly economical. As most kinds of wood placed in the ground will rot out in 8 or 10 years the larger number of timber culverts have been built only with the idea of temporary construction. In such cases it is intended to make ample allowance in size for reconstructing the culvert at some future time with durable materials, as of masonry or pipe, placing the new structure inside the old one without disturbing the embankment, which, during the life of the wooden culvert, should become well settled. Where durable timber, such as cedar, is obtainable, however, wooden culverts are sometimes built with a view to permanency. On the Canadian Pacific Ry. cedar timber is used in small culverts quite extensively and in the western parts of Washington and Oregon, where such timber is abundant, it is largely used for railway culverts. The estimated life of such timber is 150 to 200 years, as determined by the fact that almost everywhere in the cedar forests trees may be found lying in the ground partially or wholly covered, in perfectly sound condition, with other trees growing on top of them as old as the age stated. Some consider that timber of this quality will outlast many kinds of stone, where the masonry is exposed to moisture and freezing. On the Southern Pacific road timber barrel culverts built of creosoted staves are used to some extent. The material for the culvert, including the portals, is cut according to plan before creosoting. Culverts of this material are built in sizes of 24 ins., 36 ins., 48 ins., 66 ins. and 72 ins. diameter, the cost, for material and labor, not including the portals, ranging from $1.06 to $4.90 per lineal foot of pipe. There are also some locations where timber culverts are applicable to better satisfaction than others, owing to the difficulty of obtaining suitable foundations. Such is the case on marshy ground, where, in considerable depth of peat, the cost for masonry foundations would be heavy. Furthermore, peat is said to have a preserving effect on timber, while in some cases bog water has been found to act injuriously on cement and concrete.

Timber culverts of large size, or when placed under high embankments, are usually built on a flooring of 6x8-in. or 6x12-in. timbers laid on flat, and in contact, crosswise the channel. These floor timbers usually project some distance beyond the sides of the culvert—all the more so if the foundation is soft or yielding. The side walls or partitions (if any) are formed of 8x8-in., 10x10-in. or 12x12-in. timbers laid on top of one another and drift-bolted together and to the floor. In some cases the floor timbers are gained out for the side-wall timbers about 1 in., forming a shoulder to prevent the side wall from being crowded in by earth pressure. The thickness of the cover timbers may vary from 6 ins., under the outer portions of the slope, where the depth of filling is shallow, to 8 ins. farther in, and to 10 or 12 ins. under the central part of the embankment, where the filling is deepest. Of course the span and depth of filling has all to do with the thickness of the cover timbers, which are laid crosswise the culvert, with every fourth, fifth, or sixth piece notched 2 ins. over the side timbers to take the thrust of the side walls. The span of opening in timber culverts usually ranges from 3 to 6 ft., partitions being used if a single opening of the larger dimension does not afford sufficient area. Old bridge timbers are not infrequently utilized in culverts of the kind here considered, and what are known as "bridge-tie" box culverts are sometimes built of new timber. Such are constructed of 6x8-in. bridge ties laid on flat in the floor and walls, and edgewise in the covering. On the Tennessee Central Ry. culverts are constructed of oak timber, the largest openings so built being 4 ft. wide and 5 ft. high. The sub-sills are 10x12-in. timbers laid flat and the side walls are 12x12-in. timbers drift-bolted together and stepped off on the faces. The floor is laid with 2-in. oak plank and the covering of the culvert consists of 8x12-in. timbers laid flat, or 12x12-in. timbers, varying with the hight of the embankment.

An interesting application of the scheme of building a wooden culvert to be reinforced later with more durable material inside is to be found on the Chicago, Burlington & Quincy Ry., where a heavy timber barrel culvert is first constructed, and after the embankment has settled the barrel is lined with brick. These culverts, which are made as large as 6 and 8 ft. in diameter, are built of staves 10 or 12 ins. thick, according to the size of the structure, and 8 ins. wide at the outer circumference. The staves are drift-bolted together and formed over heavy rings made of old rails, spaced 10 ft. apart. These rings remain in the culvert, and to prevent distortion of the barrel where the pressure of overlying material is excessive it is propped with heavy posts, and cross bolts are placed to prevent bulging at the side. After the embankment has ceased to settle the barrel is lined with a single ring of brick placed edgewise and faced with a layer of cement mortar, and parapet walls of stone masonry are built.

Stone Box Culverts.—Masonry culverts of suitable weathering stone, if properly built, are very durable, and in localities where such material is obtainable within convenient distance it is frequently selected for permanent work. The side walls of stone box culverts are usually laid with rubble stone, and preferably in cement mortar, so as to provide for discharge under head. Water discharging under head through a dry stone box will be forced behind the walls, gradually carry out the back filling and eventually cause a washout. Sand in embankments will also find its way through the openings in such culverts, leaving cavities which will cause the roadbed to settle or lead to a washout should the culvert become surcharged. Right in this connection attention should be called to the importance of filling over and around the culvert with material which will become compact and form a barrier against filtration through the bank. If the space about a culvert is filled in with loose stones and the water becomes dammed, part of the flow will take place outside the culvert opening, and where the loose stones meet the earth filling the water will cut a hole for itself and cause a washout. Some remarks contained in a letter from Col. E. T. D. Myers to a committee of the Association of Railway Superintendents of Bridges and Buildings, in 1897, bearing on this matter, are to the point. He says, in part:

"I am persuaded that it is rather in the superior construction, the infinite painstaking to insure the safety of a culvert when it ceases to be a mere covered channel and becomes a pipe discharging under pressure. When this takes place the ordinary culvert is too apt to fail to do its duty. Between the hastily constructed dry stone box and the thoroughly-built concrete, brick, or stone culvert there is room for a legion of catastrophes. . . . . I am of the opinion that it is more often the crude method of construction than the underestimation of the area of the waterway that gives us trouble on the railroads. When a railway embankment is called upon to act as a dam, as it may be in great floods, it should possess the qualities of a dam, and the outlet from the piled-up waters above it should possess the same integrity as the drainage culvert of a reservoir. Its foundation should be as secure, its masonry as impervious, the embankment immediately surrounding it as free of voids, the inlets and outlets as carefully protected from abrasion."

Whatever the size of opening required the culvert should, if the depth of filling will admit, be made high enough to permit a man to walk through it—say 4 ft., if possible, although a less hight will answer. On some roads the minimum size of masonry box culverts is limited to convenient dimensions, as on the Northern Pacific Ry., where the smallest opening allowed is 9 sq. ft. clear of all obstructions, the hight of the opening never being less than the width. In other cases it is considered that nothing is saved in making stone box culverts smaller than 3 ft. square, for streams however small. As to width, the natural channel of sluggish streams may be contracted to some extent, where ordinary conditions prevail, but in building over rapid streams or ravines it is not safe to encroach upon the natural width of the stream as indicated by the channel which it has cut for itself. The hight of the culvert floor relatively to the surrounding surface is important. In the case of a well defined stream it is of course necessary to go at least as deep as the bed of the stream, in order to secure a suitable foundation, but in any case the culvert should be low enough to drain low-lying land without backing the water, particularly where the land is under cultivation. But unless the land falls away immediately from the outlet the culvert floor should not be lower than this. Submerged culverts are unsafe, as, sooner or later, they are almost sure to silt up and become reduced in effective area if not completely obstructed. If a channel be cut from the outlet deep enough to drain the culvert floor the culvert may be placed lower than the situation would otherwise permit.

The foundation work of culverts signifies all that the term implies in connection with other structures of permanent character. On a solid substratum, such as rock, hardpan, gravel or firm clay, the matter is easily decided upon, as then it is only necessary to prepare a smooth bed for the footing courses. On yielding ground some additional means of support should be resorted to. This may consist of a timber platform or grillage, to distribute the weight of the walls over more surface than would be possible with the footing courses; or it may consist of a bed of concrete; or a brick or concrete invert; or, if the ground is yielding to an unusual degree, it may consist of piling overlaid with a timber platform or bed of concrete. The use of timber is not advisable unless the foundation is continually submerged. For light walls the timber foundation may consist of a simple flooring of timbers laid in contact, crosswise the direction of the walls, but for heavy work a framework of crossed courses is usually required. Old bridge timbers, ties, floor beams or stringers still in fairly sound condition answer for such work just as well as new timber. On firm ground concrete is much used in footing courses, and on yielding ground it is used in beds or in the form of an invert. Except in rock or hardpan the excavation for culvert foundations should extend at least 3 ft. below the surface. It is a common fault with culverts that the side walls do not extend deeply enough into the ground, the result of which is that in freezing climates the frost heaves them up at the ends.

The original and most common covering for stone box culverts is large flat stones. In practice the thickness of cover stones is independent of the hight of embankment, being about 12 ins. for openings of 3-ft. span, 15 ins. for 4-ft. spans and 2 ft. for 6-ft. spans, which is about the widest clear opening under stone covering in general practice, although in exceptional cases there are openings as wide as 8, and even 10, ft. covered in this manner. It is usually required that cover stones shall have a bearing upon the side walls of at least 12 to 15 ins. and be laid to close joints, which should be filled and spread over with cement mortar, to form a tight covering, lest the filling material might become softened and ooze out through the openings should the culvert discharge under head.

Late years old rails, laid across the opening and covered with concrete, have been much used for culvert covering, as on most roads the material is conveniently available and such a covering gives the maximum permissible headroom under a shallow embankment. Another advantage is that in case of an unstable foundation the rail top adjusts itself better to settlement of the walls than is the case with stone covering or arches. The rail top is proportioned somewhat roughly to the load or amount of filling material supported. This may be done in one way by spacing the rails, laying them close together, with the flanges touching, under the central portion of the embankment, and spreading them apart under the sloping parts of the embankment. For heavy loads the rails may be laid in a double course by inverting the top rails so that their heads hang downward between the rails of the lower course, which stand workwise. Over long-span openings it is customary to reinforce the rails with two or more I-beams of good strength laid among the rails directly under the track, old bridge girders or floor beams being suitable for such purpose. Openings up to 12 ft. and sometimes 14 ft. clear span are covered in this manner, while rails alone, laid in a single course, are considered sufficiently strong for openings up to 8 ft. span. For spans longer than 12 ft. two openings may be used with a common pier between them. On the Portland & Rumford Falls Ry. four pairs of rails riveted together base to base, to form girders, are placed under each track rail to strengthen the covering for openings of 10-ft. span. Rails under the shallower parts of the embankment are usually spaced 6 to 12 ins. apart, according to the span of the opening, and the intervening spaces are planked or set with paving brick placed side by side upon the flanges of the rails (endwise between the webs) to form a bottom for the concrete before it has set. The rails usually extend 12 to 18 ins. over the culvert walls, according to the span. To protect the rails from rust they are usually given a coating of hot coal tar and filled in between the heads and over the tops with cement mortar, which is then covered with concrete. On the Chicago, Burlington & Quincy Ry. rail tops for culverts are laid in 6-ft. sections, separate from the walls, so that if it should become necessary to remove the same in places it can be done without badly breaking up the culvert. The concrete covering for rail-top culverts is made 4 to 18 ins. thick above the tops of the rails, according to the culvert span and hight of fill, and to provide for drainage the top surface is sloped either way from the center of the embankment. This increase in thickness of cover from the ends of the culvert toward the middle also accords with the increase of pressure from the embankment and provides some margin against a dished top in case of excessive settlement under the central portion of the embankment. Weep holes are sometimes left to permit the escape of such water as may collect. Where the grade of a culvert is very steep, as on a rock slope, the covering of the culvert, instead of being laid parallel with the floor, may be stepped, so as to better retain the filling on top. At the ends of the culvert an I-beam, channel iron, stone or concrete parapet is placed upon the rails to retain the foot of the embankment slope. This parapet is backed up by the top step or top course of the wing wall, the first stone of which is doweled to the wall underneath to resist the pressure of the embankment against the parapet.

On the New York Central & Hudson River R. R. rail tops are used on concrete or masonry culvert walls for spans of 4 to 14 ft., the larger openings that are covered in this way being under the higher banks. Old rails in weights of 60 to 100 lbs. per yd., according to the length of span, are used, being first thoroughly cleaned and then painted with a coat of red lead and oil and a second coat of bridge paint. The rails are set workwise, close together, and under each track rail the cover is reinforced with six inverted rails with the heads matched in between those of the bottom layer. The spaces between the rails are then filled with concrete made of finely broken stone or gravel, deposited in a layer 1½ ins. higher than the tops of the rails at the center and ½ in. higher at the sides. The concrete layer is covered with a ¼-in coating of American straight run coal tar pitch. The edges of the covering are finished with a concrete curb 2 ft. wide and 1 ft. thick, and in shallow banks the space above the culvert, as far as subgrade, is filled in with gravel.

For spans of 16 and 21 ft. the Cleveland, Cincinnati, Chicago & St. Louis Ry. has used a covering that is known as "concrete girder" construction. It consists of two layers of old rails embedded as a reinforcement to a thick bed of concrete, one layer of rails being near the bottom and the other near the top. For a clear span of 16 ft. the covering is 2 ft. thick, and the two layers of rails are molded in 2 ins. from the bottom and top, the top layer standing workwise and the bottom layer inverted. Under the tracks the rails in each layer are spaced 9 ins. centers, but between this and the parapets the spacing increases to 11½ ins. and 17 ins. To give the rails holding power in the concrete ⅞-in. dowels 8 ins. long were inserted in holes drilled through the web 12 ins. apart. In the construction of a covering for a double-track structure, 70 rails of 60-lb. section, 20½ ft. long, were used. For a double-track structure of 21 ft. clear span, a composite steel and concrete covering 2½ ft. thick is used. Under the tracks the rails are spaced at 9 ins. centers, as in the design for the 16-ft. span, but outside the tracks the spacing increases to 11½ ins., 17 ins., and 18 ins., centers. The rails in this case are 25 ft. long. These concrete-steel coverings, which have been applied to culvert or bridge openings on the St. Louis division, were constructed at the side of the track and rolled into place afterwards. The side walls are of concrete.

Under deep embankments the walls of culverts may be proportioned to the load, with some economy of masonry, the thickness being gradually increased from the ends, where the load vanishes, to a maximum under the central portion, where the load is greatest. Means must also be provided to prevent the walls of culverts from being forced in by the pressure of the earth filling. On rock foundation the bottom of the wall may be secured by doweling, and in the case of other foundations the paving acts as a strut to prevent crowding of the walls at the bottom. It is customary, however, to build cross walls or concrete struts between the footings, at intervals, to resist the side thrust against the walls. To secure the walls at the top it is usual to abut the rail top or stone covering against a shoulder on the top face of each wall.

In building culverts where the ground freezes to good depth in winter some attention should be directed to the conditions influenced by the quality of filling material over the top of the culvert. If this filling is shallow it will freeze deeper or harder than other parts of the embankment, being exposed both top and bottom. In such cases the filling directly over the culvert should be made with broken stone, coarse gravel, slag or other material which does not heave when frozen. The range of depth to which the necessity for such filling material applies depends, of course, upon the severity of the winters, or upon the thickness of material that will be frozen entirely through, from top to bottom. Then, too, when not deeply covered up the culvert itself is liable to be disturbed by the action of the frost, if the filling material is retentive of moisture. Owing to the action of frost and the jarring effect of trains it is desirable, at least with large culverts, to have a good depth of filling over the top. It is sometimes necessary, however, to make it as shallow as 1½ or 2 ft. Where the available headroom under the track is not sufficient for a single opening of the required area and of desired proportions the requirements may usually be fulfilled in the construction of a wider culvert of less hight, by partitioning. In such event the movement of ice and flood trash and the matter of protecting the culvert against the same may have to be taken into account.

End Construction, Paving etc.—Culverts without end walls should extend from toe to toe of the embankment slopes. It improves the general appearance of things to have the end construction conform to the slope of the embankment. In the case of box culverts, of either timber or masonry, or arch culverts of short span, this is usually done by stepping the side walls beyond the parapet, which is placed about where the top of the culvert meets the embankment slope. With masonry culverts the walls are not usually stepped lower than 3 ft. above the floor, at the end. The stepped portion of the wall should be coped with stones of good size, each step being formed by a single stone (Fig. 7 C), block rubble or roughly dressed stones being used for rubble masonry. Such end construction leaves the walls in convenient shape for the extension of the culvert should occasion arise in double-tracking the road or in the construction of side-track. In rare instances the sloping of stone culvert walls beyond the parapet is done by laying the coping stones to the slope of the wall (Fig. 11) instead of stepping them, while with concrete walls the sloped coping is found more frequently than the stepped coping. To increase the capacity of a culvert built with straight side walls from end to end, as presently considered, the face of the wall is sometimes splayed by gradually decreasing the thickness of that portion of the wall lying between the parapet and the end of the culvert, the wall remaining straight on the back side. Where drift is bothersome stepped culvert walls which run straight beyond the parapet are not considered as safe as walls carried to full hight all the way to the end, for the reason that, should the opening become clogged the full hight at the end of the wall the water may still pour into the culvert through the open top between the parapet and the end of the wall.

Culverts built to carry streams which overflow their banks at times should be provided with end walls to protect the embankment from scour by the currents which converge to the opening. End walls for culverts are of two kinds: head walls, which stand at a right angle to the axis of the culvert (Fig. 12); and wing walls, which stand at an oblique angle to said axis—15 to 45 deg., but usually about 30 deg. (Fig. 8). In either case the end wall usually serves to retain the embankment, as it usually stands on or starts from the meeting line between the top of the culvert and the embankment slope (or some little distance back of such a meeting line, depending upon the hight of the parapet). The coping of the wing wall is usually stepped to conform to the embankment slope. All coping stones should extend the full width of the wall. The earth which slopes past or around the flanks of a head wall is usually retained and protected by hand-placed riprap. To prevent undermining, head and wing walls should be carried down to good depth. For large culverts such walls usually stand at a batter.

The junction between a wing wall and the body of a culvert should be on line with the face of the side wall; that is, at the point where the side wall of the culvert joins the wing wall there should be no re-entrant angle or projection of the side wall into the splayed opening between the wing walls, such as occurs in Fig. 8. The projecting corners or shoulders impede the flow of water at the entrance between the side walls, thereby diminishing the discharging capacity of the culvert, other conditions remaining the same, and they also form lodging places for drift material. A plank or stick of timber floating against such a projection will swing around with the current and, if it be longer than the width of the culvert opening, will meet the opposite wall and become lodged across the channel and held there with great force by the pressure of the current. Danger of obstruction in this manner is greater with small culverts than with large ones, but such construction is inadvisable in any case, because the extra corners increase the cost of the masonry. One way of avoiding this projection is to build the side walls of the culvert to a batter, as in Figs. 8 A and 12 A. To avoid such projections with battered wing walls and plumb side walls it is necessary to set the wing wall inward far enough to bring it flush with the face of the side wall at the top of the culvert or springing line of the arch, and then form to a vertical face, on line with the side wall, that portion of the wing wall corner which would otherwise project into the waterway. For rapid streams of considerable volume wing walls are preferable to a head wall, on the up-stream end, as they increase the discharging capacity of the opening and facilitate the passage of drift material. The intermediate walls of partitioned culverts should be pointed or formed into a cutwater on the up-stream end to split the current and increase the flow at the entrance. On the down-stream end flared walls are not usually necessary.

The floor of a culvert should, if practicable, be laid to a grade, a fall of at least 3 or 4 ins. per rod being desirable. The grade actually required is something more than the average fall of the stream in the vicinity of the culvert. If this is exceeded the increased velocity of the stream through the culvert will keep it clear of sediment and increase the discharging capacity. In deeply covered culverts the grade should be increased over the lower third of the length so as to drain the middle portion in case the culvert sags, which is quite liable to happen, owing to the preponderance of earth pressure over the middle portion. This arrangement, in effect, gives the culvert a camber, with down grade all the way. If the culvert stands level it should be cambered a few inches to allow for sagging. Should settlement at the middle not take place to the extent anticipated, the camber that remains will do no harm, as it will only run the water to the ends in case the culvert goes dry, and possibly cause the culvert to silt up a little at the upper end, which is not so objectionable as to have the culvert sag and silt up nearly its whole length, and deepest at the middle. The sagging of culverts sometimes stretches the walls apart, but where the walls are cambered this is not liable to happen unless the settlement exceeds the amount of cambering put in. In order to prevent parting of the walls in this manner, in culverts where unusual settlement is anticipated, resort is sometimes had to means for tying the walls together longitudinally. For this purpose old bridge rods, old chain, or old rails with drift bolts through the bolt holes, have been embedded in the concrete footings for the walls.

Culvert bottoms are sometimes paved with flagstones, but more frequently with rubble stones set on edge crosswise the culvert. Such paving should be at least 12 ins. deep and, for security, the interstices should be grouted with cement mortar. A bed of concrete 6 to 12 ins. thick is also commonly used for culvert paving. Where timber grillage is used, as in submerged foundations (Fig. 8), it usually answers for the culvert floor without paving. Where stone paving is used it should be laid between the side walls, and not as a foundation for them, as in the latter case the walls are easily undermined if the paving becomes washed out. A very secure way of paving a culvert, sometimes resorted to where the current is strong, is to build masonry cross walls into the side walls, 6 to 10 ft. apart throughout the length of the culvert. These cross walls extend from the foundation up to the floor level and the paving is set in between them. At the outlet of a culvert, particularly where the water falls away rapidly, there should be a paved apron or spillway, extending some distance down stream, to prevent undermining of the foundation; and if the current is strong the bed of the stream for some distance approaching the up-stream end should also be paved. The end of culvert paving which extends beyond the opening should be protected against undermining by deeply set curbstones. The paving at the outlet is usually the more important, as, in the absence of the same, the outflow of water is liable to scour out a hole and then begin to eddy back under the pavement or masonry, causing section after section to fall in, until the culvert is finally washed out or partially destroyed. To fortify against trouble in case the paving should be washed out the end wall or foundation at this end of the culvert should be run down to good depth or to solid bottom. To prevent culverts from being clogged with ice or driftwood a fender of small piles or old rails is sometimes driven across the stream a little distance above the culvert. The piles are usually spaced 12 to 18 ins. apart, in a semicircular row extending up stream. By making the fender V-shaped up stream it will carry the drift to the shores and maintain a clear channel in the middle of the stream. If old rails are used the driftwood can be burned during dry weather without destroying the fender.

Pipe Culverts.—For small culverts vitrified clay pipe and cast iron pipe are in extensive service. In shallow embankments, where there is not sufficient hight to build a masonry culvert, pipe is commonly used, while on some roads, vitrified pipe is used under banks of considerable hight and cast iron pipe under banks of almost any hight. The chief considerations in the use of these materials are cheapness and the rapidity with which they can be laid. In filling open culverts the use of pipe affords a convenient means of maintaining an opening, and iron pipe is extensively used inside old wooden culverts that are about to fail. Vitrified clay culvert pipe is used in sizes up to 36 ins. (and even 48 ins.) diameter, although many roads limit the maximum size to 24 ins. diameter and some roads have established 18 ins. diameter as the largest size. The quality used in railroad culverts is known as "extra thick" or "double strength" pipe, being 25 to 33 per cent thicker than the clay pipe commonly used in sewers. The standard thickness of shell for railroad culvert pipe is one twelfth of the inside diameter of the pipe, while for sewer pipe the standard thickness is one fifteenth or one sixteenth of the inside diameter. The most common length of section is $2\frac{1}{2}$ ft., net, for all sizes, but 2-ft. and 3-ft. lengths are made.

Experience teaches that culvert pipe, both vitrified and iron, but particularly vitrified, must be very carefully laid if good results are to be expected. The pipe must be thoroughly bedded and given a uniform bearing. In firm earth the trench should be rounded out to fit the lower half of the pipe, as well as may be, and the earth (or preferably sand) should be well tamped about the pipe up to the center line. The precaution should also be taken to excavate suitable depressions for the pipe sockets, so that no portion of the under surface of the pipe will have to sustain more than its due proportion of pressure. The too common way of laying the bottom of the pipe on solid bearing, with only a narrow segment of the bottom wall of the pipe supported, and then filling in loose earth carelessly about the pipe, causes almost the entire pressure to fall upon a comparatively small portion of the pipe surface, thus operating to crush the pipe. The same results follow from the use of boards or timber laid in the trench to support the pipe. It is usually recommended that on soft ground the bedding for the pipe should be rammed, but the reliability of such work is questionable. On soft ground a platform of timber, or cross timbers rounded out to fit the bottom of the pipe, or a bed of broken stone, or a pile bent under or just ahead of each socket, or a brick or stone pier under each joint, is sometimes used for the immediate support, but is not generally approved of. A timber platform covered with 2 ft. of sand for the embedment of the pipe is a better arrangement, but a bed of concrete carried up half the diameter of the pipe is still better, and probably the best foundation for either vitrified or iron pipe laid on yielding ground. Without such a foundation the advisability of using vitrified pipe on ground of the character referred to is questionable. The pipe should be laid with the sockets up stream and the joints should be filled with cement mortar; on some roads both cement mortar and oakum are used. If the joints are not made tight roots may enter and choke the pipe, or when discharging under head the pressure of water may wash out cavities around the joints, leaving the pipe unevenly supported and liable to break. The cementing of the joints also strengthens the pipe at the spigot end, which, being thin and not fitting the socket snugly, obtains a bearing on the bottom only, and is liable to spring under the pressure and crush if not firmly packed about. Some manufacturers of vitrified clay pipe groove or corrugate the inside of the socket and outside of the spigot end circumferentially, to give the cement a better bond in the joint. After a joint has been made the cement should be wiped clean from the inside of the pipe, else if allowed to harden in place it may remain a permanent obstruction. Defective pieces of pipe, if at all suitable for use, should be laid next the ends of the culvert, where the pressure is light and where they can be easily removed in case of failure.

As the ground under the center of a high embankment is bound to settle, the pipe should be cambered, if anything more than in the case of masonry culverts, because the foundation of a pipe culvert is seldom carried much below the surface. As previously explained, the best way to do this is to lay the center sections somewhat higher than a plane grade from one end to the other, or lay the upper half level and then drop off from the center to the lower end. The amount of camber to be used in any case is a matter of judgment, as it depends upon the hight of the bank and the bearing properties of the top strata. Two to four per cent of the hight of the fill is sometimes allowed. The cambering of pipe culverts produces the desired effect of forcing the joints together, in case of settlement at the middle, whereas the sagging of pipe laid to an even grade stretches it apart, tending to disjoint the sections. The water which stands in a sagged pipe will cause the pipe to silt up to the same depth and reduce the area of opening by that much, and if water freezes in a vitrified pipe standing more than half full the expansion of the ice will burst the pipe. This consideration makes it undesirable to use vitrified pipe on low-lying ground or wherever water is liable to stand in the opening.

Owing to the heavy expense of replacing vitrified clay pipe in case it becomes crushed, the use of the same under high embankments does not meet with general approval, even among roads where such pipe is extensively used under different conditions. Most roads limit the use of it to embankments not higher than 20 ft., and many roads to banks of still less hight, as is the case with the Pennsylvania and Chicago, Milwaukee & St. Paul roads, where 7 ft. is the maximum fill in which vitrified pipe is used. On the St. Louis Southwestern Ry. the limiting hights of embankment for the use of vitrified pipe are 4 ft. and 18 ft. On the Nashville, Chattanooga & St. Louis Ry. the limiting fill for 18-in. vitrified clay pipe of double strength is 25 ft. high; for 24-in. vitrified pipe it is 15 ft. high. This leads up to the question, frequently raised, as to the load sustained by pipes, arches and other structures which stand under earth filling. Although earth pressure on unit areas is much of an uncertainty, the only reasonable assumption is that, with settled embankments, the load bearing upon any interior area is equivalent to the weight of a prism of the material having a base equal to the given area and length equal to the hight of material above said area. Before the embankment becomes settled the load may be more or less than this, according to the amount of friction set up between masses of settling material and the manner of distribution of the forces arising from such friction. Of these we can know nothing. Owing to the fact that a tunnel through an embankment will stand for some time without supports under the roof it has been erroneously supposed by some that the weight upon a culvert ceases to increase after a certain hight of fill is reached, or, in other words, that the load upon a culvert is not proportional to the hight of fill above it. A little reflection will dispel the fallacy. According to the tunnel hypothesis there should be no load at all upon the top of a culvert under a high fill. As a matter of fact we have no reason to suppose that the arching or beam effect of the earth, as displayed over the roof of a tunnel, existed before the material was removed from the space occupied by the tunnel. If it did we might then suppose that some portions of the interior of an embankment stand under no pressure. But this cannot be, for once pressure is removed from the material at any point there is a gradual movement of material toward the point relieved, as evinced by the bulging of the floor in deep coal mines and in tunnels through soft material. And then, if we were to assume that the distribution of earth pressure takes place through beams or arches of material, why is it not just as reasonable to suppose that the culvert will stand under the end of span of such beam or arch as that it should stand between the end supports? A simple illustration may serve to clarify this matter. In a pile of boards laid in crossed courses there is a beam over every board in the interior of the pile, and a large percentage of the boards in any course may be removed (if not consecutively) without perceptibly affecting the stability of the pile; yet if one attempts to pull boards from the interior of the pile he will find them harder to pull as he proceeds towards the bottom, showing that the beam covering any board is not called into action as such until the board is removed. So far as my reading has extended those who hold to the claims here disputed have not propounded any argument to show that the case is different with earth in an embankment. An unpropped tunnel through earth stands more firmly under a high embankment than a low one because the earth at the bottom of the high embankment is more solidly compacted, and therefore better constituted to hold together in a large mass. The pressure due to live load (the trains) is transmitted through earth filling in diverging lines and approaches uniformity with depth. It therefore acts with greatest concentration through shallow embankments and the crushing effect upon culvert pipe increases with nearness to the track. According to one rule, followed to some extent for vitrified pipe, 1½ times the diameter of the pipe is taken as the minimum allowable depth of fill over the pipe, while on some roads 3 ft., and on other roads 4 ft., is considered the least allowable depth for pipe of any diameter. Where the action of frost must be taken into account either depth seems small enough, in any case.

Culvert pipe made of concrete has been used to small extent on the Texas Midland, the Chicago & Northwestern, the Chicago, Milwaukee & St. Paul and other roads, and to a considerable extent on the Chicago, Rock Island & Pacific Ry. In some cases the results, due perhaps to improper design or workmanship, have been reported unsatisfactory, but on the road last named this kind of pipe has given good service. One advantage is that, concrete being comparatively cheap, the pipe can be made of any desired thickness requisite for strength, and as the materials of which it is made are easily transported the pipe sections can be readily made at the culvert site, thus overcoming any objections on the score of handling. Culverts of this material that have been built in municipal and highway work have given satisfactory service. The pipe is made in sizes up to 3 ft. diameter, the thickness corresponding to this size being 4 ins. The pipe is molded in the annular space between two steel-plate cylinders stood on end, concentrically. The concrete, which is formed of cement mortar and screened gravel, is tamped into the mold and allowed to set. Each cylinder is formed with an open seam and closes to a butt joint, but the edges of the plate will spring to an overlapping position if forced out of abutment. When the molding process is complete the cylinders are made removable by starting their joints with iron wedges, springing the outer one to larger diameter and displacing the edges of the inner cylinder, which permits it to spring to smaller diameter. As the implements are simple and inexpensive and skilled labor not required, such pipe can be cheaply manufactured.

On the Chicago, Rock Island & Pacific Ry. it was found that 24-in. pipe in 3-ft. lengths was best adapted for culverts, and one to seven lines of it, according to the amount of water to be carried, have been used at numerous points. The forms for molding the pipe are shown in Fig. 7. They consist essentially of an outer and inner shell formed of wooden staves and hinged together in sections, the outer shell in two sections and the inner one in three. The form for the bottom end of the mold shapes the spigot end of the pipe and a bevel-shaped form for the top of the mold shapes the socket end. The concrete is rammed into the annular space between the two wooden shells, and after setting 48 hours the forms are removed from the pipe, the outer shell opening outward and the inner shell collapsing, as shown in the figure. The manner of joining the sections together is shown at the right. The thickness of the pipe wall is 3½ ins. The concrete mixture consists of 4 parts of clean sand and gravel, just as it is taken from the pit, and 1 part of Portland cement. The cement and gravel are first thoroughly mixed in the dry condition and then water is added and the mixture is placed in the forms and rammed hard. From experience it has been learned that the pipe should not be placed for filling before it is three months old. This kind of

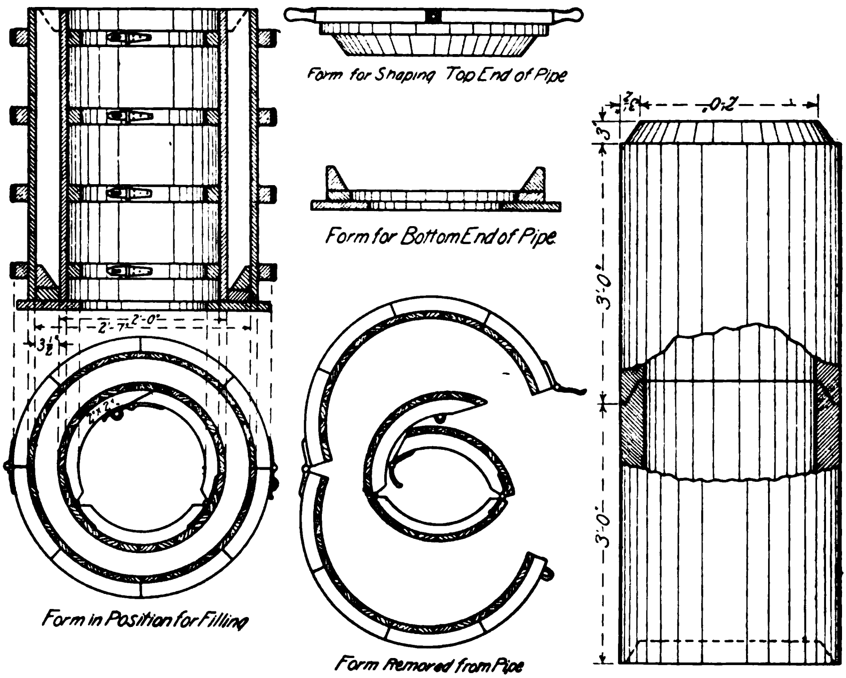


Fig. 7.—Concrete Culvert Pipe and Forms for Molding.

pipe was adopted for the class of structures in which cast iron pipe was formerly used, and at a cost which is only about one-sixth of that of iron pipe. The following are the data of materials used and costs: The solid contents of a section of 24-in. pipe 3 ft. long is 6.57 cu. ft., and the weight is 872 lbs. The material used per section is 8 cu. ft. of gravel and 2 cu. ft. of Portland cement, the discrepancy between the cubical contents and the amount of material required being due to the process of tamping. The average cost per lineal foot of 24-in. concrete pipe is 55 cents, of which the cost of the Portland cement is 35 cents, the cost of the gravel 2 cents, and the labor 18 cents. The weight of a 3-ft. section of 18-in. concrete pipe is 444 lbs., and the cost per lineal foot about 29 cents. The weight of a 3-ft. section of 30-in. concrete pipe is

1207 lbs., and the cost per lineal foot about 77 cents. At $30 per ton, the cost of cast iron pipe in that locality at the time concrete pipe was adopted, 18-in. pipe cost $2.62 per lineal foot, 24-in. pipe $3.75 per lineal foot, and 30-in. pipe $5.30 per lineal foot.

Cast iron pipe is used for culverts in sizes up to 6 ft. diameter, and segmental cast iron culverts are made as large as 7 ft. diameter. The Toledo, Peoria & Western Ry. has segmental culverts of this kind and size, and previous to 1890 the Chicago, Burlington & Quincy Ry. placed a number of such culverts, the largest being 7 ft. in diameter. With the latter road the practice was then abandoned, for several reasons, the principal one being the expense. On a number of roads cast iron pipe of 20 ins. diameter is the smallest size used, as such is about the smallest pipe that a man can crawl through and clean out. Water pipe is commonly employed for this purpose and it is quite largely the practice to select condemned water pipe, or pipe rejected for some defect which does not impair it for use in culverts. Such pipe is commonly cast in lengths of 12 ft., net—that is, exclusive of the socket—but for convenience of adjusting the length of the culvert to the width of the embankment more closely than could sometimes be done with 12-ft. lengths, odd pieces are sometimes furnished in half lengths; otherwise the pipe must be cut, which is usually done by nicking around the circumference with hammer and cold chisel. Pipe of large diameter is sometimes cast in lengths of 8 ft. Following are the usual thicknesses for water pipe of different sizes: 12-in. pipe, ¾ in. thick; 18 and 20-in. pipe, ⅞ in. thick; 24-in. pipe, 1 in. thick; 30-in. pipe, 1⅛ ins. thick; 36-in. pipe, 1¼ ins. thick; 40-in. pipe, 1½ ins. thick; 42-in. pipe, 1⅝ ins. thick; 48-in. pipe, 1¾ ins. thick; 60-in. pipe, 2 ins. thick; 72-in. pipe, 2¼ ins. thick. Standard gas pipe is 25 to 35 per cent lighter, for the various sizes, than water pipe of these thicknesses, pipe 2 ft., 3 ft., 4 ft., 5 ft., and 6 ft. in diameter being respectively ¾ in., ⅞ in., 1⅛ins., 1⅜ins. and 1½ ins. thick. The culvert specifications of quite a number of roads call for cast iron pipe of gas weights, and some for even lighter pipe. To prevent rust the pipe is coated inside and out with coal tar or asphaltum. The Chicago, Milw. & St. P. Ry. uses cast iron pipe culverts extensively, the number in service in 1903 being 4755, and the aggregate length 39.6 miles. This company manufactures its own pipe, from scrap material, on an independent design. The pipe is handled at the foundry as a by-product, a few lengths being cast at each melting. The pipe is made in 6-ft. lengths and is about 35 per cent lighter than the water pipe above referred to, the thickness of 24-in., 36-in. and 48-in. pipe being ⅝ in., ⅞ in. and 1⅛ ins., respectively. This pipe is intended mainly for service in settled banks within old wooden culverts. When used in this manner the pipe has been found strong enough, but it is not intended for use under high embankments newly made. Pipe 60 ins. in diameter and 1¼ ins. thick is also cast by this company, but owing to breakage under earth filling it is now used only occasionally.

As cast iron culvert pipe of the larger sizes is heavy (a 12-ft. length of 48-in. water pipe weighs about 4½ tons, and of 60-in. pipe about 8 tons) it is usually lifted to place with a pile driver or derrick car, if laid under track that is already built, and on new construction it is handled with block and tackle and rollers. Cast Iron pipe should not be dropped from cars upon frozen or stony ground, and when rolling it down a bank care must be taken to prevent pieces from striking against each other. It is always safer, of course, to unload it from the cars with skids and parbuckle and to restrain it with ropes in the same manner when rolling it down an embankment. To prevent crushing, it is customary to prop the inside of large culvert pipes (3 ft. diameter and larger) at intervals of a few feet and leave the supports until the embankment has settled.

In placing iron pipe inside a timber culvert the pipe is usually pulled into place from either end of the old culvert by means of block and tackle and rollers. If the opening is not large enough to admit the pipe the timber is either cut away or the top and one side, and sometimes the bottom, of the timber box are removed and the bank kept from caving by props, if necessary. Where this is done and the bottom not removed, or where there is room within the old culvert when none of the timbers are removed, it is a good plan to raise the pipe off the floor and pack the space underneath with earth. If this is not done the bottom timbers of the old culvert should be rounded out to fit the pipe, and for a short distance from each end all the timbers of the old culvert should be removed, so that no opening may exist for the entrance of water outside the pipe. In some instances where the old culvert is wide enough to receive the pipe a foundation of sand, gravel or hard clay is laid upon the old floor as a cushion for the pipe and the top is then removed to make room for the pipe. In any case earth is firmly rammed into the open space about the pipe. This work must be done as each section is pulled to place, and it is a tedious operation, but easier done with 6-ft. lengths than with 12-ft. lengths.

In laying pipe culverts through embankments where no previous opening existed the most general practice is to make an open cut, supporting the track on long stringers resting upon sills or pile bents. In order to keep the width of the cut within the limits of a desirable span for the stringers it is necessary, in deep embankments, to protect the sides of the excavation with braced planks. Under high embankments, however, it is frequently the practice to drive a tunnel, excavating an open cut well into the slope at either side, to shorten the tunnel, cutting to such slope as the earth will stand or cutting straight down and holding the faces of the cut from caving by braced sheeting. The tunnel should be made only large enough to admit the pipe or afford working room. The roof may be supported by 4-in. plank or old bridge ties, propped with center posts or side planks standing upon plank running lengthwise the opening, and held up to a snug bearing with wedges at the foot of each post. The pipe may be drawn into the tunnel on rollers or dollies, on planks laid side by side. The open space around the pipe should then be well rammed with earth or gravel. If old bridge or other timber is available for this work it may as well remain in place, but otherwise it would most likely be removed and made use of in laying other culverts. Cases have been reported of forcing cast iron culvert pipe through an embankment of soft material with hydraulic jacks, putting the pieces end to end as they are pushed in, the material being removed in advance by working it back inside the pipe.

It of course looks best and seems safest to see the ends of pipe culverts walled up, and where the current is rapid or the intake liable to be submerged at times a wall at one or both ends is usually provided. Such walls are built of rubble stone, brick or concrete masonry. They should extend below the action of frost, which will usually be low enough to prevent undermining. Protection from undermining is also largely a matter of paving outside the culvert ends, particularly at the downstream end, as already explained. By laying end walls something can be saved in length of pipe, as the wall is usually set back from the foot of the embankment a sufficient distance to bring the top of parapet on line with the slope. The best arrangement is to lay flared wing walls from the opening to the foot of slope, as then the current is converged into the channel and the foot of the embankment is protected against side currents. Such walls are sometimes arranged about the opening in the form of a semicircle. In cases where the pipe does not quite reach the desired length of the culvert, the end walls are built to project a foot or two beyond the end of the pipe. The bank around the upper end of a small vitrified pipe culvert is sometimes protected against wash by a plank bulkhead, formed by spiking plank across two posts, set on either side of the pipe, with a circular hole through the plank for the culvert pipe. Such protection is usually set at the slope of the embankment, or at least with a considerable inclination toward the roadbed. In cases such a substitute for an end wall may answer better than no protection at all, and thus serve a purpose, as when, for instance, the need of an end wall is seen where none has been built. In that case the use of a plank bulkhead until a convenient time for building a masonry wall might be advisable.

The necessity for end walls is conceded to be greater with vitrified pipe than with iron pipe culverts, owing to the more numerous joints in the former and the greater possibility that the filling may be washed from around the end sections. Owing to the short length of a vitrified section the displacement of only a small amount of supporting material will cause it to fall down, obstruct the flow of water and open the way for the undermining of the other sections, one by one. Without end walls such action is liable to take place at either end of the culvert, even where there is good paving, because the filling over the sections near the ends of the culvert is shallow, and a slight displacement of one of these sections may open a joint and let water through that will undercut the pipe. The shallow filling over the up-stream end of the culvert is also exposed to the swirl of water about the end of the pipe when such becomes submerged. At such times the scouring action of the water is particularly strong. Another occasion for an end wall at the up-stream end of the culvert is where the stream meets the pipe obliquely. In a case of this kind a strong current will tend to flow past the pipe into the bank and then eddy into the pipe. In order to minimize in length it is customary to place culverts at right angles to the embankment, without regard to the direction of the stream. This arrangement brings head walls parallel with the track, when such are built, but when a stream is crossed obliquely the end wall should be disposed in a manner to protect the bank from the impingement of the current, which can best be done by means of a wing wall to deflect the water toward the opening.

Speaking of practice generally, it seems to be the rule to dispense with end walls fully as far as, if not farther than, conditions will warrant. As a matter of fact it is not, in many cases, essential to any large economy of construction to decide upon the matter of end walls for vitrified pipe culverts when the pipe is laid. Such can be built as indications of the necessity for the same become apparent, without large expense for excavation in excess of first requirements, and the few lengths of pipe removed in setting the ends of the culvert farther into the bank, as when end walls are built, can usually be of service elsewhere. The postponement of end wall construction also gives opportunity to await the settlement of the culvert under the deep part of the embankment. Should such settlement exceed the allowance for the same there is still opportunity to lower the outer sections to correspond, at no great amount of excavation or expense, before the end walls are laid. Owing to the longer sections of iron culvert pipe, such a change is not as readily made with it as with vitrified pipe. Should the end-walling of iron pipe culverts be deferred conditionally it would be well to lay half lengths for the end sections, to be removed in case end walls are eventually built. In practice one finds various substitutes for end walls, as on the West Shore R. R., where the bank surrounding the end of the pipe is roughly dry-paved; and on the Chicago & Eastern Illinois R. R., where the ends of pipe culverts are not protected by masonry of any kind, broken stone being filled in to stop washing when it occurs.

In official reports on pipe culverts one may learn of many cases of breakage, more frequently with vitrified pipe, but to larger extent with cast iron pipe than some might suppose. Undoubtedly one very responsible cause for this can be traced to the manner in which work on pipe culverts is skimped, particularly with respect to the foundation. It is quite common experience to see culvert pipe rolled in and covered up on foundations which no man would think of accepting for masonry culverts. Almost all breakages occur under settling embankments, but where the foundation is looked to carefully and the precaution taken to prop or shore up the pipe inside until the embankment has ceased to settle, good results are usually reported. A method of strengthening cracked or broken culvert pipe of large size that is quite commonly followed is to line it with a ring of paving brick set edgewise; i. e., the 4-inch way.

To keep flood water from backing through pipe culverts and flooding property on the other side of the roadbed a backwater valve is sometimes used at the outlet end of the pipe. This device is very simple, consisting merely in a circular piece of boiler plate hinged to a pair of lugs cast or molded on at the top of the pipe. The plate covers the end of the pipe, which is cut off at an inclination, so that water flowing out of the pipe can easily lift the cover and escape, but when water backs against the end of the pipe the cover is held down by the pressure and water in quantity is prevented from flowing backward through the culvert.

Under a low embankment where there is not room for a single pipe of the desired size, two or more smaller pipes affording an equivalent area of opening are sometimes laid in a "nest." Two or more pipes are used also in place of a single opening of equal discharging capacity where the backing up of the water in order to obtain the full discharge is inadmissible. Division of the waterway in this manner does not permit the passage of driftwood, corn stalks and other flood trash so readily as a large opening of equivalent area, and the danger of clogging is an important matter to be taken into consideration. From a construction point of view the divided waterway costs more for the same area of opening, as the aggregate weight of the small pipes exceeds that of the large ones; and the labor of excavating and laying is something more for the small pipes, but not nearly in proportion to the number of pipes. When two or more pipes constituting a culvert are laid side by side they should be placed far enough apart to permit the earth filling to pack solidly between them in a column of good thickness, say as thick as the diameter of the pipe. The pipes shown in Fig. 7A are not far enough apart. The earth should be thoroughly rammed between the pipes, as well as underneath their outer quarters, and owing to the liability of one of the pipes becoming clogged and throwing the duty of discharging upon the others, the ends of the pipes should be encased in masonry or concrete end walls.

Figure 7A shows a concrete end wall for a pair of cast iron culvert pipes running through an embankment at a skew. The end of the pipe farthest from the observer is farthest from the toe of the embankment, but the construction of the end wall brings the two outlets on line with the general direction of the embankment. The plan of this end wall is therefore A-shaped. An idea suggested by this simple structure is that a culvert pipe which ends a few feet short of the toe of an embankment does not require a high end wall, which would be the case were it necessary to terminate the slope of the embankment directly over the end of the pipe. By laying a form with a core the size of the culvert pipe out as far as the toe of the embankment and depositing concrete within the same the waterway may be cheaply extended to the toe and terminated by a low end wall. The usual arrangement provided for the discharge of a culvert which serves as a cross drain from the ditch in a side-hill cut is a paved ditch or slope, which is quite liable to be washed out if the water gets to cutting under it. About the only safe arrangement of this kind is had by grouting the paving with cement mortar. Figure 7B shows a concrete spillway, consisting of a waterway 18 ins. wide and 14 ins. deep, at the top, with side walls 9 ins. thick. It takes the discharge from a 24-in. pipe and conducts it down a slope about 100 ft. long. The view shows only the upper end of the spillway, the end wall

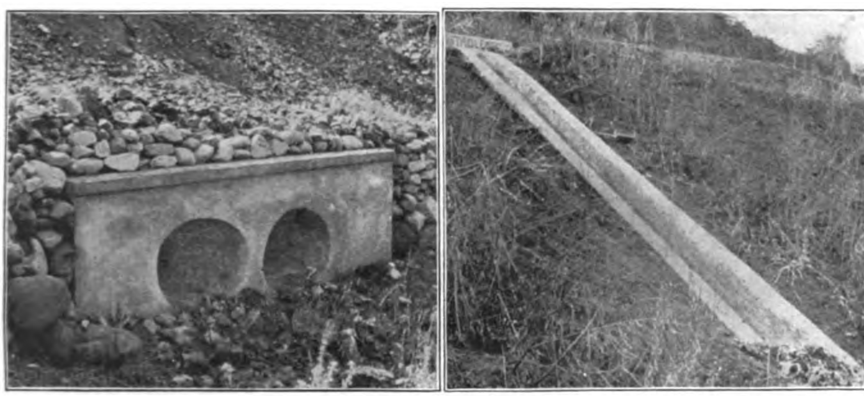


Fig. 7 A.—Concrete End Construction for Pipe Culverts—Fig. 7 B.

of the pipe culvert, also of concrete, appearing at the top of the view. As the speed of flow increases toward the bottom of the slope the depth of the waterway was made shallower at the bottom than at the top.

Wrought iron and steel plate pipes are also used in railroad culverts. The Boston & Maine R. R. has, in a few instances, used riveted wrought iron pipe in culverts standing partly full of water, the freezing of which would subject vitrified or cast iron pipe to danger of bursting. The Union Pacific R. R. has in use a large number of pipe culverts as large as 60 ins. in diameter made of steel plates ¼ to ½ in. thick riveted together with lap joints, like a boiler. This pipe cost about 75 per cent of that of cast iron pipe of the same diameter. The pipe was heavily coated inside and outside with coal tar before laying and recoated inside and outside after being laid. On the Erie R. R. there are in service some steel plate pipe culverts 60 ins. in diameter, weighing 283 lbs. per foot. The pipe is in riveted sections of 30 ft. length bolted together by flanged joints. The flange at each end of each section is formed by a 3x3-in. angle bent around the pipe and riveted to the outside. Six inches from each end there is also riveted around the outside of the pipe a 3x5-in. angle to serve as a stiffener and prevent water from coursing along the outside of the pipe. The cost of this pipe is given in the lower line in Table I, which was taken from a committee report to the Association of Railway Superintendents of Bridges and Buildings, in 1898. The other costs in the same tabulation (24-in.

to 48-in. pipe) are for steel pipe culverts on the Wisconsin Central Ry. The costs for cast iron pipe in the same table are the extreme figures (low and high) taken from a large number of replies to a circular of inquiry sent out to different roads. The cost of cast iron pipe ranged from $14.50 to $16.80 per ton, and the cost of stone masonry end walls from $4 to $8 per cubic yard. The "total" columns do not include the cost of masonry end walls. The Nichols "portable" culvert is of trapezoidal cross section, with the widest side on the bottom. It is made of steel plates riveted to angle irons and is stiffened with angle irons on the outside, giving a smooth surface inside. At each end there is a steel plate portal and wing walls. This structure is brought to the site of the culvert ready made, to be placed upon a prepared foundation. The steel is painted with some preparation to protect it from rust.

Brick Barrel Culverts.—Hard burned brick is very durable material, and well designed structures built therewith are practically everlasting. In municipal work brick barrel sewers are very commonly found, and where conditions will permit of laying them they are consid-

TABLE I.

COST PER LINEAL FOOT OF CAST-IRON PIPE CULVERTS.

Size of pipe.	Material.	Labor.	Total.	Cost of stone masonry ends.
18-inch	$1.11	$0.16	$1.27	
20-inch	1.00 to 1.62	.09 to 1.06	1.76 to 2.08	$43.00
24-inch	1.20 to 3.32	.17 to 1.82	2.09 to 5.19	53.00 to 69.12
30-inch	1.22 to 2.90	.23 to 1.42	3.09 to 4.67	66.00
36-inch	2.51 to 3.69	.30 to 1.64	2.81 to 6.50	78.00
42-inch	3.35 to 5.00	.70 to 1.96	5.08 to 5.70	90.00
48-inch	4.30 to 7.70	.36 to 3.12	5.29 to 10.32	100.00
60-inch	7.94 to 10.61	1.26 to 2.66	10.60 to 11.82	

COST PER LINEAL FOOT OF STEEL PIPE CULVERTS.

Diameter of pipe.	Material.	Labor.	Total.
24-inch	$1.12	$0.12	$1.24
30-inch	1.55	.17	1.72
36-inch	2.28	.25	2.53
42-inch	3.00	.30	3.30
48-inch	4.13	.46	4.59
60-inch	8.25	.45	8.70

ered the best waterways that can be built for the purpose. To some extent such work has been imitated in railway culverts. The culvert is laid by rounding out the bottom of the trench to give shape to the lower half of the "barrel," and then the brick rings are laid in cement mortar directly upon the rounded surface of the ground, up to the hight of the horizontal diameter, when forms are placed and the cylindrical structure is completed by arching over the top. Of course such culverts can be built to give satisfactory service only where there is firm earth to support the bottom and under quarters of the structure. Such culverts are used extensively on the Nashville, Chattanooga & St. Louis Ry., in sizes from 3 to 5 ft. in diameter, and on ground which is not firm enough for such construction brick barrel culverts backed up with haunch walls are used in sizes from 3 to 6 ft. diameter. The thickness of the barrel culverts is one ring less than the diameter of the culvert in feet, the brick being laid edgewise in each ring. The bricks used are all very hard burned, but those having vitrified surfaces are selected for the paving of the bottom semicircle. Table II., taken from a paper by Mr. Hunter McDonald, chief engineer of this road, presented before the Engineering Association of the South, gives the cost data of these culverts, as well as of vitrified and cast iron pipe and stone box culverts. The term "brick arch" found in this tabulation is not applied in the strict sense, as the opening in these culverts is circular, the same as with the brick barrel culverts. The distinction between the two designs is in the use of haunch walls in the so-called "brick arch" culverts, to strengthen the barrel, as above stated. These haunch walls are of such thickness that the width of the culvert masonry over the haunch walls, is equal to twice the diameter of the interior of the barrel. The haunch walls are carried up full width as high as the horizontal diameter of the barrel, above which they slope off rapidly to meet the top of the barrel on tangent. The reason for substituting this design for a brick arch with straight side walls and an invert of comparatively large radius is that, for a usual thing, the foundations are in alluvial soil and are somewhat treacherous. By using the semicircular invert, or rather a circular culvert with haunch walls, the load on the culvert is distributed over the entire bottom surface, with the certainty that the invert will not be pushed up into the culvert, which might be the case if the invert was flat—that is, of comparatively large radius. Where it is neces-

Table II.—Data on Culverts, N. C. & St. L. Ry.

KIND OF CULVERT	Area of opening.	Minimum discharge per minute. Fall 1 in 200.	Lin. ft. of Culvert between Parapets.						Pa'p't complete for 1 Cul.			
			Am't of material.	Cost of material.	Labor excava'g.	Labor building.	Total cost.	Cost per sq. foot of opening.	Cost of material.	Labor excava'g.	Labor building.	Total cost.
Clay pipe:												
1-18 in.	1.77	464.7	....	$ 0 43	$ 03	$ 08	$ 54	$ .305	$ 7 77	$ 20	$ 2 28	$ 10 25
2-18	3.54	929.4	....	86	06	16	1 08	.305	14 83	30	3 45	18 58
1-24	3.14	958.3	....	86	05	10	1 01	.321	9 43	24	3 03	12 70
2-24	6.28	1916.6	....	1 72	07	20	1 99	.317	16 30	36	4 14	20 80
30	4.91	1679.3	....	1 58	06	12	1 76	.360	12 78	40	3 30	16 48
Iron pipe:			Iron.									
18 in.	1.77	464.7	150 lbs.	$ 1 24	$ 03	$ 18	$ 1 45	$ .82	$ 7 77	$ 20	$2 28	$ 10 25
24	3.14	958.3	208	1 72	06	24	2 02	.643	9 43	24	3 03	12 70
30	4.91	1679.3	300	2 48	07	36	2 85	.58	12 78	40	3 30	16 48
36	7.07	2651.0	417	3 44	07	36	3 87	.547	14 79	52	4 28	19 59
43	12.57	5416.0	750	6 19	09	48	6 76	.537	20 80	1 22	6 72	28 74
60	19.63	9444.0	1250	10 31	10	60	11 01	.561	36 37	2 60	14 40	53 37
72	28.27	14816.0	1500	12 38	12	72	13 22	.468	38 80	3 80	16 02	58 62
Brick bbl.:												
36 in.	7.07	2651.0	132 brick	$ 85	$ 09	$ 85	$ 1 79	$ .253	$22 11	$ 66	$10 00	$ 32 77
48	12.57	5416.0	286	1 83	11	1 30	3 24	.258	45 92	1 54	20 56	68 02
Brick arch:												
36 in.	7.07	2651.0	250	1 60	10	1 33	3 03	.428	22 11	66	10 00	32 77
48	12.57	5416.0	372	2 38	16	1 89	4 43	.352	42 68	1 54	18 16	62 38
60	19.63	9444.0	560	3 58	22	2 49	6 29	.320	62 81	2 20	28 50	93 51
72	28.27	14816.0	840	5 38	32	3 30	9 00	.318	73 65	4 20	33 15	111 00
Stone box:			Mason'y									
2x4 ft	8.00	1684.0	1.33yds	$ 3 36	$ 11	$2 52	$ 5 99	$ .75	$56 45	$ 1 92	$42 43	$ 100 80
3x4	12.00	3903.0	1.463	3 69	13	2 77	6 59	.55	60 98	2 20	45 59	108 77
4x5	20.00	7920.0	1.77	4 45	18	3 34	7 97	.398	78 88	4 00	57 93	140 81
4x6	24.00	10145.0	2.065	5 25	23	3 81	9 29	.388	108 36	6 00	79 05	193 41

DATA USED IN COMPUTING ABOVE COSTS.

CLAY PIPE.	IRON PIPE.	BRICK CULVERTS.	STONE CULVERTS.
18 in. Pipe $1.07 per 2½ ft. joint	18 in at 1800 lbs per 12 ft. j't.	Brick 2½x4x8 at $4.50 per M.	Stone per cu yd. $2.00
24 " " $2.15 per 2½ ft joint	24 " 2500 " "	Brick per c ft. 16 4 allowing ⅜ in. joint	Cement ½bbl .45
Building Parapets $3 per M. brick	30 " 3600 " "	Mortar, 1 part Cement 2 parts sand	Sand 1 bbl. 07
Coping Stone 27 and 31c per lin. ft.	36 " 5000 " "	Cement .81 bbls. per cu yard, or:	Labor 1.98
Apron Stone 25c per lin. foot	48 " 9000 " "	Cement 1.83 bbls per M b·ick	Total..... $4.50
	60 " 15000 " "	Coping Stone 31c per lin. foot	
	72 " 18000 " "	Apron Stone $1.50 per cubic yard	
	All at $16.50 per 2000 lbs		

NOTE.—All prices F. O. B. Nashville, February, 1898.

sary to increase the hight of these culverts for any purpose other than that of increasing the area of the culvert opening, as, for instance, to allow for the passage of cattle, straight side walls 2 ft. high are put in between the upper and lower semicircles of the culvert and the haunch walls are carried up in proportion. Wherever the nature of the foundation will permit, brick arches with straight side walls and a comparatively flat invert are built. A particular culvert of this class (Fig. 7C) under a 60 ft. embankment has a semicircular arch of 7 ft. span, straight side walls 3½ ft. high, and an invert of 7 ft. radius. The foundation consists of five rows of piles driven about 3 ft. apart in each row, around the tops of which is placed a bed of concrete 2 ft. deep. Haunch walls are carried up to a hight of 7 ft. 9 ins. above the foundation and then sloped off rapidly to meet the top of the arch on tangent. The width over the haunch walls at the foundation is 14 ft. and the batter on the back sides of these walls about 1 in 10, making the top width 12 ft. 5 ins. The plain barrel culverts are used only on hard, firm ground, where the natural surface is above the axis of the culvert and where the hight of the earth above the culvert does not exceed 30 ft. Haunch-wall circular culverts are used wherever the brick barrel will not answer,

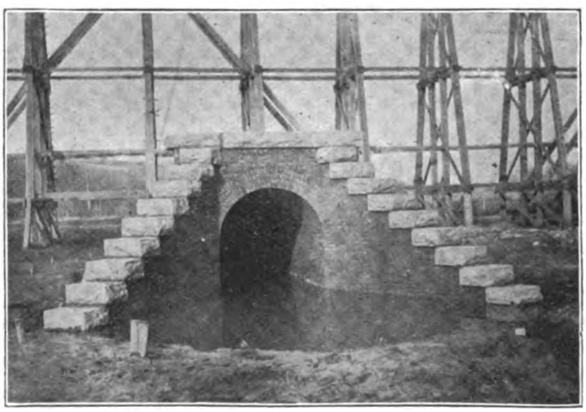


Fig. 7 C.—Brick Arch Culvert, N., C. & St. L. Ry.

and an extra ring of brick is added to the arch for every 15 ft. of fill over 20 ft. high. On solid rock bottom semicircular arches with straight side walls are used. The minimum grade of the culvert floor is ½ per cent. In the haunch-wall circular culverts the barrel is not made as strong as in the plain barrel culverts, as in the former only two rings of brick are used up to and including culverts of 5 ft. diameter. The culvert of 6 ft. diameter of this class has 3 rings of brick. It will be noticed that the culvert shown in Fig. 7C has vertical wing walls and that there are no re-entrant angles at the end of the arched opening.

Arch Culverts.—Well constructed stone arches are considered the highest class of masonry for culverts and bridges, and on many of the best built roads such is the standard construction. Particularly is this the case on the Pennsylvania R. R., where many fine examples of heavy arch construction are to be found. It cannot be expected to here go into the subject of arch construction and masonry specifications comprehensively, but some ruling principles may be considered. In railway work semicircular and segmental arches predominate, with an increasing preference for the segmental arch. This for the reasons that the segmental arch permits of a wider opening where the depth of embankment is a limiting feature (Fig. 7D, for example), and the amount of sheeting in the semicircular arch is the greater and therefore the more expensive, particularly in cut-stone work. First-class work calls, of course, for dressed sheeting stones, but roughly dressed and rubble stones are very commonly used in arches of short span, having quarry-faced stones with chisel draught edge lines for ring stones. The Canadian Pacific Ry. builds rubble masonry arches as large as 60 ft. span, the only cut stone used being in the ring courses or those which show at the ends of the arch. This kind of work laid in Portland cement mortar has cost about $6 per cubic yard, and, owing to the long distance over which cement must be hauled, is considered cheaper than concrete. For abutments and wing walls rock-faced ashlar masonry is quite frequently found in high-class work, while range work and broken ashlar are very common. In the smaller culverts rubble masonry throughout is quite general.

Figure 8, showing the plans of a stone arch culvert of 20-ft. span located near Watervliet, Mich., on the Chicago & West Michigan division of the Pere Marquette R. R., represents a good example of durable con-

Fig. 7 D.—Flat Arch Culvert Construction.

struction for openings of this size. The arch is 29 ft. long, and the total length of the structure, from end to end of wing walls, is 76½ ft. The arch is segmental, with moderate rise to span, the arc or central angle being 139 deg. 58 min., the rise 7 ft. and the radius at the intrados 10 ft. 7¾ ins. The arch sheeting is 2 ft thick and the spandrel walls 2½ ft. thick and 3 ft. 11⅝ ins. high at the crown. The filling over the arch crown, or the distance from the crown to the base of rail is 9 ft. 4 ins. The abutment walls of the arch are 9 ft. 9 ins. high to the springing line. The excavation was carried 4½ ft. below the surface of the water and the foundation consists of timbers placed at 3 ft. centers and overlaid with two crossed courses of 3-in. plank. The wing walls are 24½ ft. long, and open out at an angle of 30 deg. with the center line of the arch. The footing course of the wing wall where it joins the arch abutment is 8 ft. wide, and at the base of the battered portion the wall is 6 ft. wide. The outward face of the wing wall is battered 1 in 12 and on the back the batter is 1½ in 12. The material is sandstone, from Grafton, Ohio. The stone was scabbled at the quarry and required but little cutting to prepare the top and bottom beds. The joints and beds for 10 ins. back from the face were laid in Portland cement mortar and the balance in Louisville cement mortar, except that all the joints in the arch were laid entirely in Portland cement. The centers were struck nine days after the keystone was set. The arch was built under a long trestle which was filled in after the work was completed. The cost of the work was as follows: Stone at the quarry, $1986.06; freight, $1298.21; foundation timber, $502.20; foundation plank, $453.34; 1041 cu. yds. dry excavation, @25c, $260.25; 617 cu. yds. wet excavation, @ 75c, $462.75; 594 cu. yds. channel excavation, @ 25c, $148.50; 495.9 cu. yds. stone cutting and laying, @ $7.50, $3719.25; extra labor $31.90. The cost for material was then $4239.81, the cost for labor $4622.65 and the total cost $8862.46. The cost of the stone work was $14.12 per

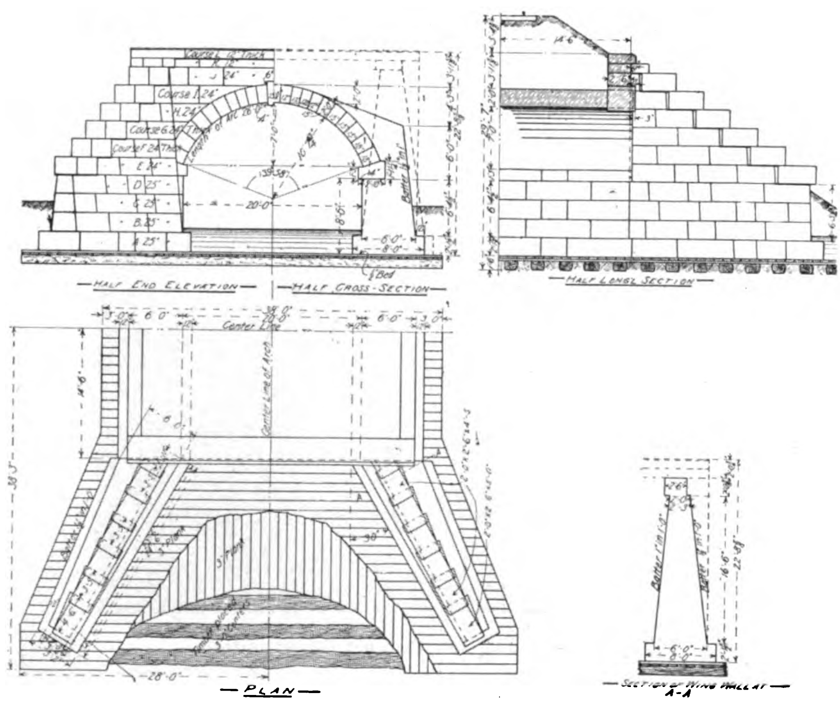


Fig. 8.—Plans of Stone Arch Culvert, Pere Marquette R. R.

cubic yard, of which the cost of the stone at the quarry was $4, the freight $2.62 and the cost of the cutting and laying $7.50.

Figure 8A shows the general plans of the stone arch culverts of 15 ft. span built on the reconstructed Wyoming division of the Union Pacific R. R. The wing walls flare out at an angle of 25½ deg. with the axis of the culvert and they extend 24 ft. 5 ins. from the face of the arch. The reader will take notice of the inclined side walls of the culvert, an arrangement which avoids the objectionable re-entering angles at the mouth of the opening, or where the side walls meet the wing walls.

In most localities where suitable building stone is not to be had within convenient distance good brick, being so widely manufactured that long shipments are seldom necessary, are usually cheaper for masonry construction and quite as satisfactory, so far as durability is concerned. Aside from the cost of material there is also the important advantage that brick can be handled without derricks. In building culverts under track already laid the brick can be delivered to convenient points about the work by unloading from the cars into chutes, whereas in unloading and setting stone of the larger dimensions derricks are a practical necessity; and the expense of moving derricks from place to place, erecting, and operating the same is a considerable figure. Where the bench and wing walls of brick arches are laid with brick or rubble stone the only heavy stones to be handled are the coping stones, and these, being comparatively few, can be moved to place with hand tools. Instance where this principle is carried into effect may be found with the Chicago, Milwaukee & St. Paul Ry., where some arch culverts of considerable span are constructed entirely of brick except for the coping stones. Brick for culverts should be hard burned, laid in Portland cement mortar, and the various rings composing the arch sheeting should be bonded together at intervals. For large contracts the brick are sometimes, but infrequently, molded bevel-shape, to fit the radial lines of the arch. The Atchison, Topeka & Santa Fe Ry. makes extensive use of rubble arches with brick sheeting. Figure 9 shows Bridge No. 200 on the Chicago division, near Chillicothe, Ill. The span of this culvert (or "bridge") is 30 ft. and the arch is semicircular or "full centered," with 6-ft. bench walls, making the headroom 21 ft. at the center. The arch sheeting has six rings of Galesburg paving brick laid on edge in Portland cement mortar. The footing for each abutment wall consists of a bed of Portland cement concrete 7 ft. deep, on a gravel bottom. The rub-

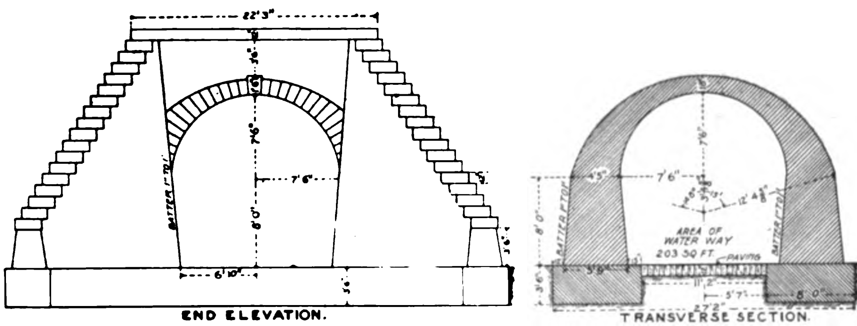


Fig. 8 A.—Standard 15-ft. Arch Culvert, Union Pacific R. R.

ble masonry is laid with natural cement mortar. Owing to the compactness of the gravel in the bed of the stream the culvert is not paved and has not shown any need of paving. This culvert drains 5.38 sq. miles of broken country and at times water 10 ft. deep has flown through it. Bridge No. 201 is a semicircular arch of 14 ft. span, with 8-ft. bench walls, through an embankment 54 ft. high. There are four rings of brick in the arch and the remainder of the masonry is rubble stone. The foundation for each abutment wall is a bed of concrete 3½ ft. deep resting on piles driven 13½ ft. into hard clay. The piles are not capped and extend 1½ ft. into the concrete. Bridge No. 202 is the same size as No. 201 and is built like it except that only three rings of brick are used in the arch, the embankment being but 21 ft. high. Each abutment foundation consists of a bed of concrete 3½ ft. deep resting upon hard blue clay. Both of these culverts are paved with stone, 14 ins. deep, between concrete head walls 2 ft. wide and 3 ft. deep, to hold the paving in place and protect it against undermining. The tops of the head walls come flush with the top of the paving. Between Chicago and Kansas City on this road there are 65 arches ranging from 8 to 30 ft. span, built similarly to the ones here described.

Figure 10 is a progress view of a brick culvert of 8 ft. span under a 63-ft. embankment on the Cincinnati Southern Ry. The culvert is

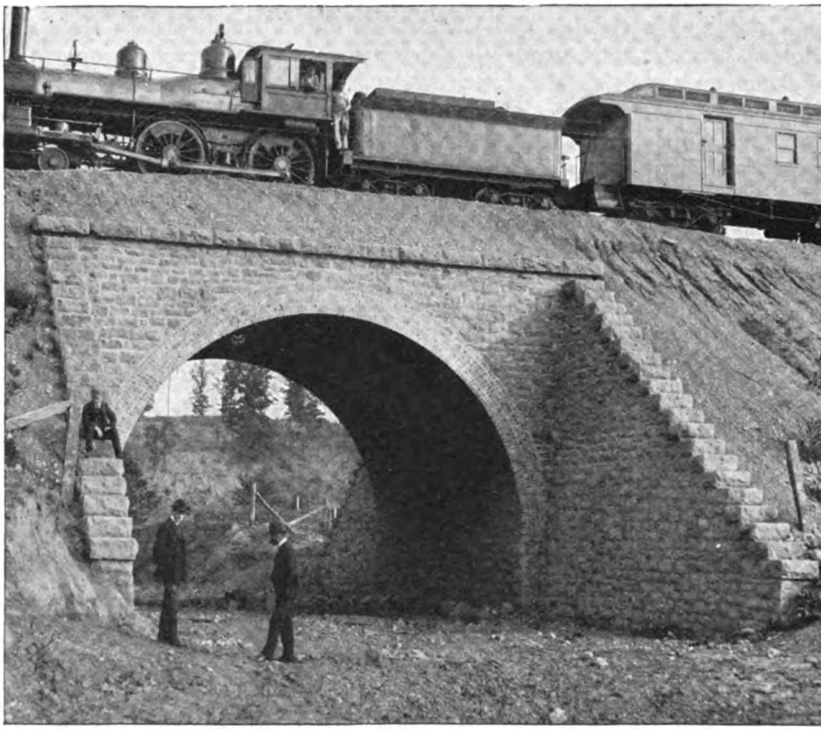


Fig. 9.—Brick and Stone Arch Culvert, A., T. & S. F. Ry.

207 ft. long and, owing to banks at either side of the fill, the culvert had to be built on a skew of 65 deg. with the alignment of the road. The foundation of the culvert consists of concrete walls 4 ft. 9 ins. wide and 4 to 7 ft. deep. Upon these walls there are brick bench walls 3 ft. 5 ins. wide and 4 ft. high. The arch is semicircular and consists of four rings of brick set on edge, backed up with brick haunch walls carried out to the full width of the bench walls and carried up nearly to the top of the arch. These haunch walls had not been laid when the photograph was taken. The end of the arch is finished with brick broken to the face line, as shown in the figure. The culvert is paved with one layer of brick set on edge on a concrete foundation 12 ins. deep. The paving is sloped from either side to form a depression along the middle line of the culvert. Figure 11 shows a culvert of 8 ft, span under a freight yard of the New York, New Haven & Hartford R. R., at Montello, Mass. The culvert is 700 ft. long, and has a solid concrete invert and foundation, with granite side walls, brick arch with concrete backing, and end walls of granite.

Concrete Culverts.—Late years railroad masonry work has been running much to concrete, this material being found particularly well adapted for foundations, retaining walls and culverts. Monolithic work is the rule, large abutments, arch culverts and the like being formed in a single mass. An important advantage with concrete masonry, from the standpoint of economy, is that skilled labor is not required in laying it, which is not the case with stone masonry or brickwork. Carpenters are usually employed to erect the forms and ordinary laborers mix and deposit the material. In ordinary work the forms are easily set up and

Fig. 10.—Brick Arch Skew Culvert, Cincinnati Southern Ry.

the lumber used in the same may be taken down and used over and over. The usual form is made by standing a row of posts in line and lightly nailing on boards or 2-in. planks horizontally for each face of the wall, using planks surfaced one side and two edges if smooth work is desired. The posts usually stand higher than the wall and are braced to stakes driven into the ground; to posts or piles in trestle bents, in case the culvert is built under a bridge; or to other stable objects. To prevent spreading the form apart as the concrete is deposited and rammed the posts on opposite sides are held together with tie rods, top and bottom, the latter remaining in the concrete when the form is removed. On extensive work the concrete is generally mixed with portable machinery. Concrete culverts are usually built either as arches or with rail tops, with any form of end wall construction that is desired. The coping of wing walls in concrete masonry is usually sloped to conform to the embankment slope.

An example of a rail-top culvert built with concrete side and end walls is shown in Fig. 12. It has two openings each 4 ft. wide and 8 ft. high, with a 3-ft. partition between. The head wall on either end of the culvert is 36 ft. long, 2½ ft. wide on top and 14 ft. deep, the back of the

Fig. 11.—Brick Arch Culvert, Stone Trimmed, N. Y., N. H. & H. R. R.

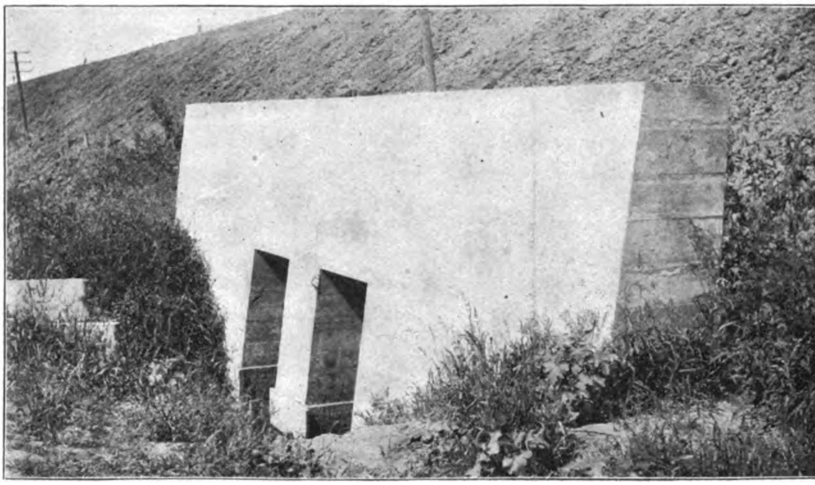


Fig. 12—Concrete Culvert, C., B. & Q. Ry.

wall being vertical and the face battered 1¼ ins. to the foot. The side walls of the culvert are 2½ ft. thick at the top, next the covering, vertical on the inside and battered 1 in. to the foot on the back. The top of the culvert is covered with old rails in 7-ft. lengths spaced 12 ins. centers and filled over with a concrete covering 18 ins. deep. This covering was laid on forms placed in the top of the openings and left in place until the concrete had set, so that the concrete forms a solid mass both between and over the rail supports. The entire masonry work of the culvert is laid upon a grillage of old stringers. The photograph from which this view was reproduced was taken over the edge of the bank, so that the stream and its channel are hidden from sight.

Concrete arch culverts of ordinary spans are now extensively found on railways throughout the country, but not as numerously east of the Alle-

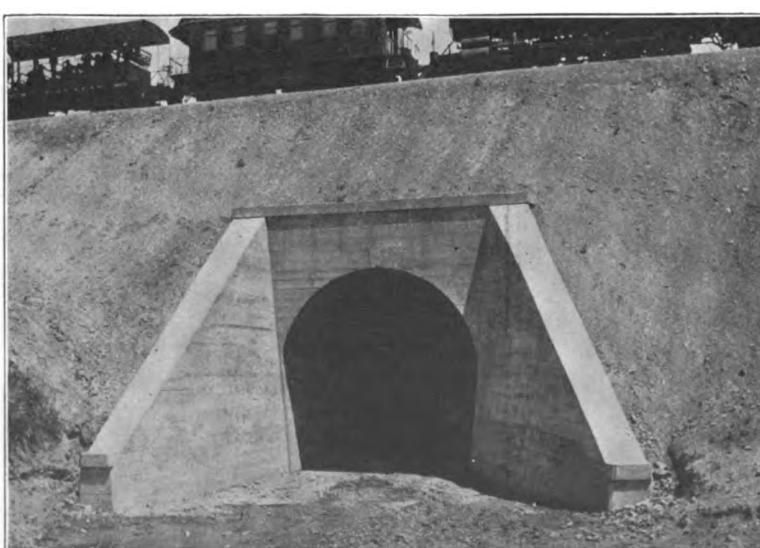


Fig. 12 A.—Concrete Culvert, 20-ft. Span, Union Pacific R. R.

gheny mountains as west of them. A good example of such construction is illustrated in Fig. 12A, being one of the standard structures of this class on the Union Pacific R. R. The side or bench walls of this culvert are 8 ft. thick at the bottom, and are battered on the inside face 1 in 12, so as to meet the battered wing walls without making a re-entrant angle. The arch is full centered or semicircular and is 24 ins. thick at the crown. The clear opening under the crown of the arch is 20 ft. and the length of the culvert is 97 ft. The Chicago, Burlington & Quincy Ry., on its Iowa divisions, has built numerous arch culverts having concrete side walls, wing walls and face walls, but with brick rings. Under high embankments these culverts are built in sections not to exceed 40 ft. in length, with tarred paper between the sections, so that unusual settlement will not break up the solid masonry. This principle of construction is applied to both arch and rail-top culverts on this and other roads. In some of the culverts of the Missouri, Kansas & Texas Ry. burnt clay ballast has been used as a substitute for broken stone in the concrete.

Reinforced Concrete Arch Culverts.—One of the recent developments in the use of concrete in arch construction is the reinforcement of the masonry with steel members. This scheme saves something in concrete, at least in large structures, and binds the material together in such a way

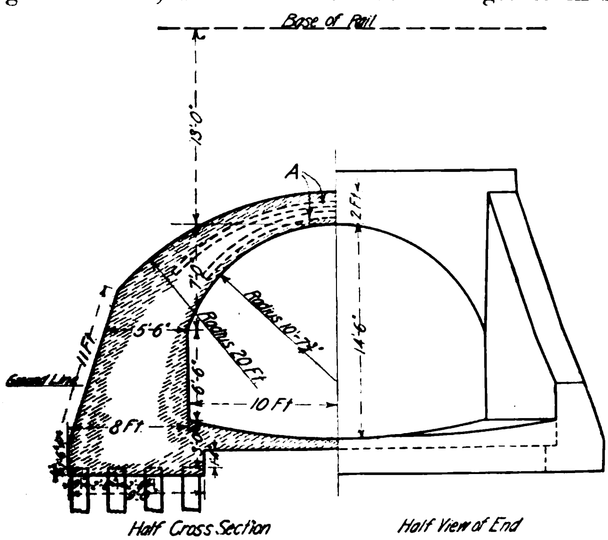


Fig. 12 B.—Reinforced Concrete Arch Culvert, L., E. & D. R. Ry.

that it is not liable to be greatly weakened in case of settlement under high embankments or from lack of uniformity in foundations. In practice there are various types or designs of reinforcement. In some cases expanded metal of No. 10 gage and 3-in. mesh has been embedded in the arch ring, side walls, face and wing walls of concrete culverts. In the standard concrete arch culverts of the New York Central & Hudson River R. R. a netting of No. 8 galvanized wire, mesh 1x2 ins., is embedded in the arch ring.

On quite a number of roads the reinforcing members consist of steel rails embedded in the arch ring. As used on the Lake Erie & Detroit River Ry. these rails are curved to the arch, as illustrated in Fig. 12B, which is a part section and end elevation of a culvert over Little Cedar creek, 29 miles east of Walkerville, Ontario. The arch is 51 ft. long, face to face, and, covering a width of 24 ft. divided across the middle line, there are ten track rails, curved workwise and embedded in the concrete. The abutment and wing walls stand upon a foundation of four rows of live oak piles, spaced 2½x3 ft., driven to a depth of about 16 ft. and cut off at an elevation 6 ins. above the lower limit of the concrete work. The principal dimensions appear on the drawing. The spandrel walls are 2½ ft. thick and extend 1½ ft. above the crown of the arch. The wing walls are 22 ft. long and open out at an angle of 12 deg. Up to the springing line of the arch the face of each wing wall stands vertical, thus permitting it to meet the face of the abutment wall at a vertical corner and avoiding a re-entrant angle. Above the springing line the wing walls are slightly battered and finished without coping at a slope of 1.7 to 1 from the ground line, which is 6 ft. above foundation. The paving of the culvert is a flat inverted arch of concrete 12 ins. thick on the center line and 20 ins. thick at the abutment walls. The paving extends the entire length of the opening between the wing walls, or 95 ft. from end to end, and is curbed at either end with a concrete wall 2 ft. thick and 2½ ft. deep. The material of which the arch is composed consists of 1 part of Portland cement to 2 parts of clean, sharp sand and 3 parts of crushed stone. The concrete in the remainder of the work is composed of 1 part Portland cement to 3 parts of sand and 5 parts of crushed stone. To protect the back of the arch and abutment walls those surfaces were covered with a layer of asphaltum applied hot. The volume of masonry in the structure is 785 cu. yds. The total cost of the culvert was $6700. On the Grand Trunk Western Ry. segmental arch concrete culverts are reinforced with straight pieces of old rail embedded in the arch ring crosswise the barrel of the arch. In this manner they pass close to the intrados at the top of the arch and extend out toward the extrados at the haunches, being cut to such length that the ends of the rail do not project from the arch ring. The spacing of these reinforcing rails is 2 ft. centers under the tracks, increasing to 2½ ft. and then to 3 ft. centers towards the ends of the barrel.

The Luten type of reinforcement, which has been applied to a number of culverts on the Cleveland, Cincinnati, Chicago & St. Louis Ry., consists in the use of single rods passing through those portions of the arch which are in tension when the structure is under live load. The arrangement is illustrated in Fig. 12C. The span of this arch is 18 ft., the clear opening 9 ft.; the curve of the intrados is three-centered, with radii of 5 ft. at the haunches and a radius of 12 ft. under the crown. The thickness at the crown is 17 ins., at the springing line 30 ins. and at the base of the abutments 7 ft. The reinforcing rods, which are smooth, round and 1 in. in diam., are embedded near the intrados at the crown and near the extrados at the haunches, crossing the ring at points of minimum bending moments. They are thus arranged with the intention

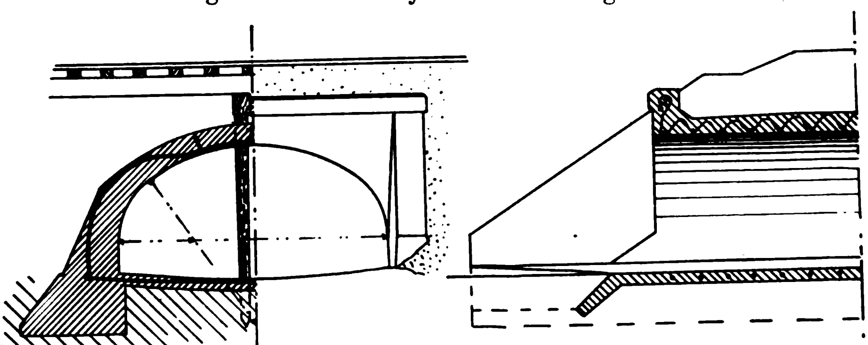


Fig. 12 C.—Reinforced Concrete Culvert at Acton, Ind., C., C., C. & St. L. Ry.

of putting them in tension their entire length. They are spaced at intervals of 2 ft. To resist the horizontal thrust of the arch steel tie rods running from abutment to abutment are joined to the arch rods and embedded in the pavement of concrete in the bed of the stream. Each horizontal tie rod is bent around its corresponding upper rod and then hooked to the adjacent or the second rod from that one, thus bonding the bench wall together longitudinally by either a single or a double row of rods at the base of the wall. The arch and bench walls were built in radial sections of 10 ft., corresponding to the work of each day, and at the base of the abutment or bench walls the sections are bonded together with old steel rails embedded lengthwise the arch or parallel to the opening. The arch replaced an old timber trestle, and was constructed around a pile bent which remained standing in openings through the arch ring until the centers of the arch were struck. The track was then supported by blocking the stringers directly upon the crown until the openings were filled with concrete, the traffic being permitted to pass at ordinary speeds while the work of filling was under way.

The Illinois Central R. R. has built a large number of concrete culverts and bridges (in spans up to 140 ft.) in a variety of forms. One class of structure used for culverts of 10 to 15 ft. span consists of a very flat type of concrete arch reinforced with straight I-beams. It is the rail-top principle of construction with the concrete finished to a three-centered flat arch underneath. The 15-ft. spans have seven 9-in. I-beams 17½ ft. long spaced at 18 ins. centers under each track and embedded in the concrete, which is 18 ins. thick at the crown—3 ins. thick below the beams and 6 ins. thick above them. The top surface of the concrete is flat, except at the sides, where it slopes to 4-in. drain tiles through the parapet or face wall. Over a segment of 11 ft. the intrados is curved to a radius of 20 ft., and at the haunches the radius is 2 ft. The culverts of 12 ft. span have a radius of 16 ft., for a chord of 8 ft., and haunch curves of 2 ft. radius. The reinforcement in these culverts consists of five 10-in. or 12-in. I-beams 16 ft. long under each track, spaced 2 ft. apart. In one double arch culvert the 12-in. I-beams are continuous over both of the 12-ft. arches. For the 10-ft. spans the reinforcement consists of five lines of 10-in. I-beams 14 ft. long, spaced 2 ft. apart under each track. The radii of the intrados are 16 ft. for a chord of 6 ft., and 2 ft. at the haunches. Many of these culverts have concrete inverts 8 ins. thick. In many instances the depth of filling over the culvert is only 18 ins. of ballast, measuring from the top of the concrete to the bottom of the ties. On this road numerous stone arch culverts and bridges have been repaired with a lining or casing of concrete to protect the stone from further disintegration. At one place the arch of a culvert of 16 ft. span was lined with concrete 8 ins. thick and the bench and wing walls were encased with concrete of the same thickness. In some cases a concrete invert has been placed and the bench and wing walls have been faced with concrete, without lining the arch. An account of lining a stone arch of 50 ft. span with concrete (Philadelphia & Reading Ry.) was published in the Railway and Engineering Review of March 31, 1900.

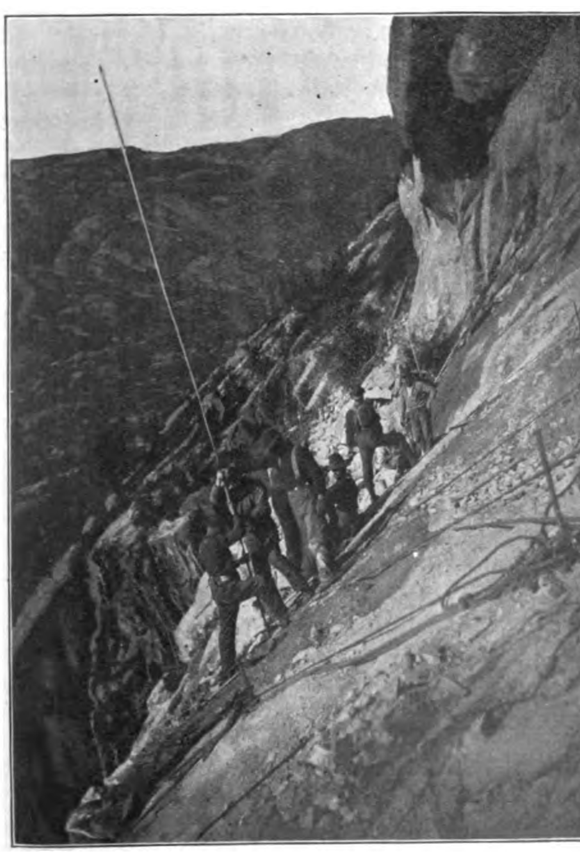
General Considerations.—By way of general conclusion on the subject of culverts it may be said that, as far as is feasible, all structures under the track should be made permanent. The cost of renewing a structure at the end of a period more or less certain is not the only factor to be taken into consideration when figuring out the economy of temporary construction. The service rendered by a temporary structure usually calls for a good deal of the time of the section men, sooner or later, which means interruptions to the track work, but which are not always counted upon in reckoning the ultimate cost of a temporary structure. In building a road where the culverts must be constructed of material shipped in, and particularly if of large stone or heavy pipe, temporary trestles are usually constructed at the openings in the roadbed and the culvert work and filling are taken up in convenient season.

One object which should be continually before the mind of the engineer of construction should be to reduce as far as may be practicable the number of openings under the track. Thus, for instance, the locations for cattle passes may frequently be selected at points where culverts are required, although to do this, in some cases, may require a little diplomacy with the farmers, perhaps. Otherwise there is liable to be a temptation, and one too frequently yielded to, to dispose of such openings with inferior construction, such as pile bents with plank bulkheads, open culverts, or other openings which answer to the same description. If the location of a cattle pass does not call for construction adapted to the flow of water it should nevertheless measure up to the standard of requirements for the roadbed and track, and rail-top culverts or arched masonry openings are to be recommended. The opening of ordinary size for this purpose is 7 ft. high and 5 ft. wide. Where no water is to be carried wing walls are not provided. On some concrete arch cattle passes the barrel of the arch is carried out to, and finished off at, the plane of the embankment slope.

In some situations it is possible to do away with culverts entirely, even where a stream must be taken care of, as in the case where the road crosses a loop in a stream and the scheme of cutting a channel to shunt the stream across on the up-stream side of the track is practicable. In each case of this kind two culverts can be avoided. A remarkable application of this scheme of engineering may be seen just east of Ft. Steele, Wyo., on the Union Pacific R. R. Here the road crosses a bend in the bed of a stream emerging from a canyon through which a great deal of water passes when snow melts in the spring. Within the loop the road cuts across the end of a rocky bluff, and in order to divert the course of the stream, so as to save two culverts, a tunnel 360 ft. long, 6 ft. high and 5 ft. wide was cut through the rock.

There is also a scheme, sometimes resorted to, for shortening the length of a culvert where a fill is made across a narrow and deep ravine. In place of a culvert through the lowest part of the embankment, which in some cases would have to be several hundred feet long, the ravine is filled with loose rock for some distance up from the bottom and provision is made for carrying off flood water by putting in a culvert at a high level and cutting a drain into the solid bank, on one or both sides of the ravine, so that in case the water cannot all find its way through the permeable embankment, the upper opening or openings will prevent the flood from rising to dangerous hight. With such an arrangement, however, there is some question as to whether the ravine would not in time fill with sediment and debris to the level of the culvert. With a culvert of ample size there would appear to be no particular objection to this plan of construction, but, except in rock formation, the necessity for providing a substantial pavement or spillway to prevent wash from the outlet might entail enough expense to offset what was saved in length of culvert. It is to be considered, however, that, as between two openings of the same size, the water will flow away more rapidly through the lower one, should the opening prove to be inadequate to pass the water freely, owing to the greater head possible. It is also true that the lower the culvert is placed, the less likely is the flood water to rise to the level of the track, owing to the increase of flow with head.

A notable example of the application of this principle of construction is the Cascade rock fill on the Erie R. R., near Gulf Summit, 184 miles from New York City. Here the road crosses a narrow gorge formerly spanned by a bridge 275 ft. long and 175 ft. high above the stream. In 1850 this gorge was filled, the bottom part with slaty rock in thicknesses up to 18 ins. The embankment is 480 ft. wide at the bottom of the ravine, and the sides, which are faced with earth, gravel and cinders, stand at slopes varying from 1.58:1 to 1.44:1. This ravine drains about 5 sq. miles of territory, and during ordinary times the permeable rock fill passes the water. Usually the water stands in a pool about 15 ft. deep, but at times this goes almost dry. To provide for floods a tunnel 320 ft. long and 10x13½ ft. in section was cut through the rocky bluff on one side of the ravine, 53 ft. above the normal water level in the pool (the bottom of the tunnel is 96 ft. below grade), and in times of heavy rain or rapid thawing the water rises to this tunnel; frequently the discharge has been known to almost fill the tunnel. The spillway from the tunnel is over solid rock. Apparently the rock in the bottom of this embankment has not been silted to a level higher than 10 or 15 ft. Observation during a period of 12 years (1888 to 1900) showed no change in the normal level of the water passing through the fill.



Building Track Foundation Under Difficulties, White Pass & Yukon Route.

CHAPTER II.

TRACK MATERIALS.

6. Rails.—Among track materials the rail has received more study or careful attention at the hands of engineers than any other one thing, and it has been greatly improved and cheapened. Improvement in the quality of the metal and the decline in cost of manufacture began with the introduction on a commercial scale of that great invention, the Bessemer process of making steel. A Bessemer steel rail was laid on the Midland Ry., in England, as early as 1857, but the behavior of most of the Bessemer steel rails rolled at about that time is reported to have been unsatisfactory, and for seven or eight years their manufacture was abandoned. The first steel rails made in the United States were of Bessemer steel and were rolled in Chicago in May, 1865; the first Bessemer steel rails to be produced on commercial order were rolled in Johnstown, Pa., in August, 1867. Practically all of the rails now in service in main tracks in this country are of Bessemer steel. Iron rails have gone out of use, except possibly on a few unimportant roads where the volume of the traffic has not been sufficient to wear them out, or where they have been taken from main tracks and put into side-tracks. The introduction of the Bessemer process fairly revolutionized the art of rail manufacture and the ultimate effect upon railway building can hardly be overestimated. The cheaper product has made possible the heavier rail of recent years, not to speak of thousands of miles of new lines which, in all probability, but for this cheaper product would not now exist; and this heavier rail, with its increase of strength, has made possible the heavier locomotives and cars of greater carrying capacity now everywhere employed. The amount of historical data essential to anything like a comprehensive statement of rail development would overswell convenient limits of space in this book; hence the story can only be touched upon, and that in a rather disconnected way.

Weight of Rails.—Looked at directly from a financial standpoint, the question which first arises in construction is the weight of rail to be used. Concerning this matter fixed rules are not in fashion, nor, except at more or less wide extremes, can conclusive evidence be deduced from practice which will decide upon anything like a definite weight for the case in hand. First of all, with new roads a prediction of the amount of business for the first few years, at least, must always be something of an uncertainty; but even with old roads which do a good business, and where the amount of it is fairly well established, there is not, in the nature of things, opportunity to clearly demonstrate the most economical weight of rail within perhaps 15 or 20 lbs. per yard. To appreciate the force of this statement one must be able to understand how numerous, how varying, and how indeterminate are the conditions which must be taken into consideration. It is a question depending more upon judgment, as the term is commonly understood, than upon direct or conclusive demonstration. Some general principles are recognized, however, which cannot be far from the facts.

Views respecting the minimum weight which can be profitably used accord pretty closely. It is safe to say that no standard-gage steam road constructed to-day with a view to permanency could afford to use in main track a rail lighter than 60 lbs. per yard. Roads not operating more than ten trains per day, unless the locomotives were unusually heavy, would probably not save anything in the end by going much above this. Within limitations quite generally understood, the logical guide in weight of rail is volume of traffic. When the amount of traffic is known, something approximate to the increased service in years, per added weight of rail, can be ascertained, but just what saving in repairs can be effected by an additional outlay for so many extra tons of rail per mile, as required by the section of increased weight, cannot be stated with any degree of certainty. It is known that there is a saving in repairs by any increase of section, but where such increase reaches the point at which saving in repairs plus the saving due to added life of rail, is balanced by interest on additional outlay, plus depreciation on the extra weight which must go to scrap, cannot be stated with any greater accuracy. Any road making the change to larger section can appreciate the results, and a road doing a paying business is not so liable to feel the cost, even though it may use a rail somewhat heavier than actually results in economy. A company earning large profits could the more easily be induced to adopt a rail of heavy section; and profits have been made the basis for judgment in more instances, perhaps, than has the amount of traffic. Increase in size or weight of rails has been an empirical growth. Increase in wheel loads and in speeds was necessarily accompanied by increased deflection in the rails and greater depression of the track into the ballast, thus calling for more work to maintain the track in surface. When observations of this character made the rail appear too weak the section would be made somewhat heavier, until it seemed to answer the requirements fairly well. It is true of practice to say that the relative amount of work required to keep the rails in desired surface has been the index which has governed rail design so far as the weight was concerned. The conditions of rail support are such that stresses in the rails from the loads imposed by the traffic are not determinable from mathematical calculations—at any rate no man of experience has made bold to propose a method of theoretical investigation of the problem. It remained for Mr. P. H. Dudley, within recent years, to show, by means of his "stremmatograph," what the magnitude of the stresses in rails really were. This is done by actual measurement of the strains in the fibers of the rail base, from which the stresses are deduced by a well known process. The subject is dealt with in some detail in § 181, Chap. XI.

It seems a striking coincidence that, with no attempt at complying with formulated rules, the average weight of rails has maintained a pretty nearly fixed relation with the average weight of locomotives. It is not far out of the way to express this relation by saying that the average weight of rail in pounds per yard has corresponded to the average weight of locomotives in tons. In the days of 50-ton locomotives we had the 50-lb. rail, and later on there were 60-lb. and 70-lb. rails to meet a corresponding increase in weight of locomotives. At present we have 80-ton locomotives and 80-lb. rails in pretty general service, while 100-lb. rails are in use on about as many roads as are 100-ton locomotives. On a comparatively few roads locomotive weights have advanced a good deal beyond 100 tons, but such cases are too rare for the purpose of the present comparison. While it may be true that increase in weight of rails relatively to the increase in weight of locomotives may have been a little tardy, at times, it is nevertheless a fact that the developments along the two lines have moved parallel.

Rails weighing 75 or 80 lbs. per yard are ordinarily found on lines of heavy traffic.* A few years ago it appeared that tendencies were strongly set toward the general use of 100-lb rails in the near future, but the gain in that direction has been slower than was expected. As a matter of history 80-lb. rails (5-inch) were first used in 1884, on the New York Central & Hudson River R. R.; 95-lb. rails (5-inch) in 1891, on the Boston & Albany R. R.; and 100-lb. rails (6-inch) in 1892, on the New York Central & Hudson River R. R. The entire line of the Boston & Albany road (202 miles of double track) was completely laid with 95-lb rails in 1897, the latest section then used having the following dimensions: hight, $5^1/_{32}$ in.; width of base, $5\frac{1}{2}$ ins.; width of head at bottom corners, 3 ins.; sides of head sloping 1 in 16; depth of head, $1^9/_{16}$ in.; depth of flange, 1 in.; thickness of web at middle $\frac{5}{8}$ in.; radius of top of head and of side of web, 14 ins.; fishing angles, 14 deg.; radius of top corners of head and of bottom fillets, $^5/_{16}$ in.; radius of top fillets, $\frac{1}{2}$ in.; radius of bottom corners of head $\frac{1}{8}$ in.; radius of corners of flange, $^1/_{16}$ in.; edge thickness of flange $^5/_{16}$ in.; web $\frac{1}{8}$ in. thicker next the base than under the head. The earliest roads besides the N. Y. C. & H. R. R. R. to begin the use of 100-lb. rails were the New York, New Haven and Hartford; the Pennsylvania; the Chesapeake & Ohio; the Pittsburg, Bessemer & Lake Erie; the Duluth & Iron Range; the Buffalo, Rochester & Pittsburg; the Pittsburg & Western; the Canadian Pacific and the Lehigh Valley. During the eight years after 100-lb rails were first put into service in this country, the total length of track laid with the same was only about 2200 miles, of which the Penna. R. R. had 1085 miles and the N. Y., N. H. & H. R. R. 500 miles, but since then the increase in the mileage of rails of this weight has perhaps been more rapid. Some of the 100-lb. rails are of the American Society of Civil Engineers' standard section and others are of independent design. The rail in use on the New York Central & Hudson River R. R. is 6 ins. high, $5\frac{1}{2}$ ins. wide on base and 3 ins. wide at the bottom corners of the head. The depth of head is $1\frac{5}{8}$ ins.; depth of flange, $^{31}/_{32}$ in.; edge thickness of flange, $^9/_{32}$ in.; thickness of web at narrowest part, $^{19}/_{32}$ in.; web $^7/_{32}$ in. thicker next the base than next the head; radius of bottom corners of head $^1/_{16}$ in. In other respects the section is shaped like, and has the same dimensions as, that of the 95-lb. rail of the Boston & Albany R. R., above referred to. The remarkable features of the section are the broad and shallow head and the unusual hight, the latter contributing to increased stiffness. The metal is distributed in head, web and flange in the proportion of 40.8, 23.5 and 35.7 per cent. The section of the 100-lb. rail in use on the Pennsylvania R. R. (Fig. 19) differs materially, the dimensions being as follows: hight, $5\frac{1}{2}$ ins.; width of base $5\frac{1}{2}$ ins.; width of head at bottom corners, $2^{13}/_{16}$ ins.; sides of head slope 4 deg.; depth of head $1\frac{3}{4}$ ins.; depth of flange, $^{15}/_{16}$ in.; thickness of web at middle, $\frac{5}{8}$ in.; radius of top of head, 10 ins.; radius of top corners, $^7/_{16}$ in; radius of fillets, $\frac{1}{4}$ in.; radius of side of web, 8 ins.; fishing angles, 13 deg.; distribution of metal in head 46 per cent, in base 34 per cent, in web 20 per cent. The 100-lb. section of the New York, New Haven & Hartford R. R. has the same general dimensions as that of the New York Central & Hudson River R. R., except that the head is narrower and

*Heavy traffic, as determined by a committee of "reporters" to the International Railway Congress, in 1900, is supposed to comprise a movement of 10,000 or more trains per year (27 or more trains per day) on one track, or that number on each track of a double-track line.

deeper, the width at bottom corners being $2\frac{3}{4}$ ins. and the depth $1^{23}/_{32}$ ins. The radius of top corners is $^{7}/_{16}$ in., fillet radius $\frac{1}{4}$ in., fishing angles 13 deg., radius of side of web and top of head 12 ins., depth of flange $^{15}/_{16}$ in., web same thickness at base as under the head. The distribution of metal is as follows: head, 41.65 per cent; web, 23.65 per cent; flange, 34.70 per cent.

Rail Design.—For convenience the cross section of the rail is quite easily divided into three distinct parts—head, web and base or flange. Conventionally described, the head includes all the metal above its under sides produced to meet in the vertical axis of the section, the greatest depth being shown by dimension *E*, Fig. 13. The base or flange includes all the metal under its upper sides produced to meet in the vertical axis of the section, the greatest thickness being shown by dimension *G* in the figure. The web includes the remaining metal, or that between the head and flange, the hight of which is shown by dimension *F* in the figure. Regarding the relative proportions of these three parts there has been much discussion. Inasmuch as but little of the metal is usually lost by oxidation or rust, the head is the only portion which usually wears out, and the idea which prevailed for a long time was to put into it as much metal as conditions affecting the other parts would allow. The most important of these conditions arises during the process of manufacture. As the flange is thinner than the head it naturally cools more rapidly, both during and immediately after the rolling process, and if the quantity of metal in the head greatly preponderates that in the flange the disparity in the rate of cooling of the two parts is correspondingly large. In order to produce a straight rail, therefore, it must, after the last pass through the rolls and before it is placed upon the hot bed to cool, be given an amount of camber or upward curvature which varies with the excess of metal in the head over that of the flange; so that at high heat the head is made longer than, or is curved around, the flange. Now while steel is cooling down from the rolling or finishing temperature there are certain stages at which there is, for an instant, a retardation in the falling of the temperature, and sometimes there is a perceptible increase of heat. These stages are known as "points of recalescence" or "critical points." Steel containing less than 0.20 per cent carbon has three of these points, at 1580, 1365 and 1200 deg. F., while ordinary rail steel, with 0.45 to 0.55 per cent carbon, has only one, which lies between 1290 and 1340 deg. F. The phenomena observed in the cooling of a rail from the finishing temperature are about as follows: After cooling a little there is at first a recalescence of the flange, straightening the rail and giving it a slight downward curvature, and later a recalescence of the head, giving the rail camber or upward curvature, frequently exceeding the amount first put into it, until finally it begins to straighten for the third time, and after 40 to 45 minutes, when cool, the rail is approximately straight and is finished by gagging, or straightening under a press.

The effect of this unequal cooling is to produce strains in the metal, as indicated by the flexure, and so far as permanent set takes place in the interior of the metal the strength of the rail is affected. That permanent set does occur in cooling is shown by the fact that the rail does not cool straight; and then to get it straight it must be bent in the cold condition and be given more permanent set. It thus occurs that in order to produce rails of desired quality the design must in large measure suit the conditions of manufacture. These conditions improve as the quantities of metal in head and flange approach an equality, and the preponderance of enlightened opinion stands for that form of section in which these two parts are as nearly balanced as the purposes of the rail and economy of material will seem to permit. With this twofold object in view the aim respecting the distribution of the metal is to minimize the necessary amount of initial camber, and therefore the severity of the cooling strains and the amount of gagging necessary; for the greater the amount of camber used the greater is the liability to kinking while the rail is cooling. Experience has also shown that the life of a rail depends but relatively little upon the amount of metal in the head available for wear, as is explained further along—the dependence in this respect is rather upon the wearing properties of the metal, for in practice the rail usually becomes unserviceable after only a relatively small portion of the head has worn away. The old idea that the rail head should be deep has been pretty thoroughly explained away. Examples in the distribution of the metal over the section have already been referred to, and further along the subject is again taken up.

After settling upon the distribution of the metal in the three parts of the rail, the next matter for consideration is the exact form and dimensions of these parts. Perhaps first in importance is the relation between the hight of the rail and the width of the flange. As strength and stiffness increase very rapidly with increase in hight of section, that dimension should be as large as is consistent with stability and the proper proportioning of the parts. The idea sometimes advanced that a rail can be too stiff for the rolling stock is absurd. This idea probably takes its inception from the fact that rough track in stone ballast (which is the hardest and stiffest ballast) is more severe on rolling stock than in other kinds of ballast; but stiffer rails in such a case would be beneficial. Rails of available weight cannot be made as stiff as it is desirable to have them. Assuming that the cross sections of rails of different weights are similar (This is not strictly true, but the approximation is close enough for practical considerations), it follows from mechanical laws that the strength (measured by safe load) varies as the cube of the hight and the stiffness (measured inversely by deflection) as the fourth power of the hight. For example, a rail 5 ins. high is practically twice as strong and 2.4 times as stiff as one 4 ins. high, although it is only $1\frac{1}{4}$ times as heavy. An 80-lb. rail (hight 5 ins.), which is $33\frac{1}{3}$ per cent heavier than a 60-lb. rail (hight $4\frac{1}{4}$ ins.), is 62 per cent stronger and 91 per cent stiffer. The increase of stiffness with hight of section in rails of the same weight is also surprisingly large. Although the stiffness of the track does not increase in proportion to increase of stiffness in the rail (the supporting power of the ballast and roadbed having to be taken into account), nevertheless the relative stiffness of the rail is an important matter in maintenance economy. Increase of stiffness in the rail distributes the load farther from the bearing point—that is, over more ties—thus reducing the pressure per unit area of the ballast and roadbed, which reduces the rate of settlement of the track. It is also to be noted that stiff rails do not cut into the ties as badly as the more flexible ones. That stiffness could be carried much farther than it is in practice, without making the rail too weak laterally, is true; but to do so would necessarily draw metal from and weaken the flange, which, for reasons to be stated, is not advisable.

The points of advantage in a wide flange are that it distributes the load over more tie surface, thus operating less destructively upon soft ties; it gives the rail side stability and it also gives it stability against canting or tilting on curves. Of such importance are the claims for both high rail and wide flange (and the fact that one cannot be carried far without affecting the dimensions of the other) that, in the largest practice, a compromise has been struck at making the two equal. Any variation in this relation is usually in favor of the hight, but not more than ½ in., in the largest rails.

As to the proportions of the head, everything seems to favor the broad head as against the deep one. The wider the head the wider is the bearing for the wheel tread, the effect of which should be to prolong the life of both rail and wheel. The shallower head broadened out adapts itself much better to rolling, as it cools more quickly than the deep one and thus reduces the cooling strains. The broader and thinner head also makes room for deeper and thicker angle bars—a matter of great importance as affecting the stiffness of rail splices.

Concerning the top of the rail head some claim that it should be flat, while others go farther and say that it should be flat and also inclined to correspond to the coning of the wheels. It is supposed that thereby the tractive power of locomotives would be slightly increased and that the treads of wheels instead of wearing concave and reversing the conicity, as really does happen, would better retain their original form as wear takes place. It is also claimed for the flat-top rail that flow of metal and consequent scaling of the head, from wheel pressure, cannot so readily take place. Against these claims it is argued that while the flat-top rail would undoubtedly increase to some extent the tractive power of the locomotive, at the same time the resistance which such a rail would offer to rolling wheels would be greater, so that, after all, the effectiveness of the locomotive would not be increased, if indeed it would not be very much diminished. As a reason for this it is explained that on flat-headed rails wheels run with considerable noise, while with the same wheels on a rail having a radial top the noise is very much less. As noise in machinery indicates wear and loss of power, it is inferred that such is the case with wheels running on a flat surface; and hence a compromise between reduced locomotive traction on the one hand, and added rail resistance to wheels, on the other, is arrived at by shaping the top of the rail head to a comparatively long radius, 10 and 14 ins. being the minimum and maximum in common use.

It was formerly taught that friction is independent of extent of surface except at limits of abrasion. It is generally conceded now, although not well formulated as yet, that this does not apply to rolling friction, at least, but that rolling friction decreases with decrease of bearing surface, and hence, for car wheels, both train resistance and wear on the rail are less for the radial-top rail. Regarding the traction of the locomotive it is well known that driver tires soon wear to fit any shape of rail head, for which reason any loss in tractive power due to small bearing surface for the driver will take place during only a short time while the tire is new, or immediately after it has been turned down. It is also pointed out that the side play in the wheel is bound to wear the tread hollow, and the hollow tread will in turn wear the rail head to a curve. Repeated observation of this mutual wear has shown that the rail top is worn approximately to a curve of 12 ins. radius, whatever the shape of the head. While this consequence may not follow as quickly with a flat-top as with a radial-top rail the same result is nevertheless eventual. So far as bearing is concerned the worn tread obtains full bearing upon rails with curved top, but as for new wheels on a radial-top rail the ideal conditions are supposed to obtain, so that, taking conditions as they are bound to occur, everything seems to favor the rail with a curved top. Facts above stated explain why a curve of 12 ins. radius is considered the natural shape of the rail top. The practice of increasing this radius is defended by those who favor it, on the ground that the larger the top radius the less severely is the head indented by the gags in the straightening press during manufacture.

There is another argument put forth to prove that the rail having the radial top reduces the rolling friction of wheels to a minimum. The coning of wheels is practiced for two reasons; viz. to effect a slight gain of speed of the outer wheel over the inner one on curves, and to facilitate the adjustment of the speed difference of two wheels on the same axle having slightly different diameters. It is the latter reason which it is desired to consider here. It will occur to any one that to always get two wheels of exactly the same diameter on the same axle must be a difficult matter; also that a difference in hardness between the metals in the two wheels will result sooner or later in a difference in diameters from the unequal wear. Were the wheel treads cylindrical this difference of diameters would cause the wheel of larger diameter to constantly outrun its mate, so that the axle would always take a position somewhat diagonally to the track, keeping the flange of the wheel of smaller diameter constantly grinding against the rail. If the tread of the wheel is coned, however, there is a constant adjustment of the wheels from one side to the other; for just as soon as one wheel is crowded over against its rail it is then rolling on a portion of its tread which is of larger diameter, and it sooner or later is able to gain on the other wheel and swing the axle back into line. This action can be observed of any pair of coned wheels running on straight track. The movement of the wheels, first to one side and then to the other, is not therefore an indication of a wrong condition, but that the wheels are properly adjusting themselves to difference in speed, and therefore to least resistance. If the wheels take a straight course, keeping always to one side, it may be inferred that their diameters are not the same, and that the constant running of one flange against the same rail increases the resistance. Now this coning of the wheels will give the desired effect on a rail head of any uniform shape, but another point arises in connection with the coning. Suppose the rail head be flat and beveled to correspond to the coning of the wheel. The contact between tread and rail may then be likened to a straight line drawn squarely across the rail head. Now the points of the tread in contact with the rail at opposite ends of this line—that is, at the gage side, and at the outside, of the rail head—are points on the extremities of unequal diameters. This means that in running a bevel-treaded or coned wheel on a bevel-headed rail, one part of the tread in contact with the rail must constantly slip ahead or else the opposite part slip back, or else both forward and backward slippings take place at the same time, as with reference to a point at the center of the line of contact, thus increasing the rolling friction of the wheel to some extent and consequently the abrasion of the rail. The force necessary to constrain a conical pail to roll straight across the floor furnishes a familiar illustration of the wasted power here referred to in the action of the wheel on the flat-top rail. With regard to the matter of abrasion, however, it might be disputed that the flat-top rail suffers the more in the end, especially when considering the effect of locomotive drivers; or it might be shown that locomotive drivers operate more severely on the radial-top rail, while ordinary car wheels, which are not so heavily loaded and which hold the coning longer, are more severe on the flat-top rail. Where, however, the top surface of the rail head is curved, the contact between wheel tread and rail is a point, or, more correctly, a small circle or ellipse, and consequently a speed difference between the outer and inner portions of the rolling tread in contact does not occur. The radial-top head undoubtedly contributes toward a minimum of rolling friction between wheel and rail as long as the coning lasts. After that the conditions would seem to be about the same in either case.

Ideas on the necessity for wide contact between wheel and rail have led to the practice of tilting the rail to fit the coning of new wheels. On European roads and in India it is the general practice to adz the ties to give the rail an inward cant of 1 in 20. This practice has been adopted on the Lehigh Valley road, in this country, where the rail (90-lb.) is canted ¼ in. toward the inside. Aside from the increased traction which this arrangement is supposed to afford, it does give considerable side stability to the outer rail on curves, some claiming that it answers every purpose of the use of rail braces. On European roads it is found that on straight track the pressure of the wheel on the canted rail has a tendency to cant the rail more, and does actually narrow the gage. On curves the tendency to cant toward the inside is opposed by the centrifugal pressure from the wheel flanges and the gage tends to widen.

Another point in rail design upon which opinions differ is in regard to the side of the head—whether it should be vertical or sloping. It was formerly the practice to use sloping heads more than it is now, the idea being that the side of the head should fit the wheel flange and thus remove the cause of vertically worn flanges. On this point opinion has largely changed, and there are now but comparatively few who endorse the principle of the flaring head. The evil effect of flange wear lies not necessarily in vertically-worn flanges more than any other, but in flanges so worn as to grind against the side of the rail head. As such takes place sooner on rails with a sloping or flaring head than on rails having a head with vertical sides, the preference would seem to be with the vertical side. As between wheels worn to fit the rail the state of things would seem to be the more favorable with the vertical-sided rail head and vertically-worn wheel flange, because on a sloping head there must be greater tendency for the wheel to climb the rail. For the same quantity of metal in the head the sloping side narrows the bearing for the wheel tread, and unless such rails are gaged at the top corner of the head there is permitted a considerable amount of side play in the wheels in addition to the customary clearance of ⅜ in. + wear of flange. It should be noted that, by reason of the closer fit of the wheel to the rail, this excess play is greater than the amount of slope or batter in the side of the head. With gages of the usual form (having vertically depending lugs) it is not practicable to gage the rails from the top corners, and, as a matter of practice, they are not so gaged. In some cases the gage lugs are shortened and the gage of the track is taken at a point midway up the side of the rail head. In other cases gages with ordinary lugs are used, and consequently the gage is measured at the lower corner of the rail head, such being the case on the New York Central & Hudson River R. R. It has been the practice on the Lehigh Valley R. R. to measure the gage from a point ½ in. below top of head.

The rail section designed by Mr. Robert H. Sayre for the Lehigh Valley R. R. many years ago has always been the criterion of rails with side-sloping heads. Formerly the side slope in the head of this rail was 10 deg., but in 1891 a modified section was adopted in which the slope was reduced to 5 deg. In 1899 this design was abandoned by the Lehigh Valley company for the American Society standard section, described farther along. The extreme of designs opposed to the wheel-fitting idea is found in the "pear-head" rail, in which the sides of the head slope inward from the top.

Rails of this shape are standard on some of the roads in Europe, but in American practice the idea has never been strongly entertained, although it has been tried to a small extent.

The point over which the largest amount of discussion has taken place is in regard to the radius of the top corners of the head. Authorities on the subject now advocate radii varying all the way from $\frac{1}{4}$ to $\frac{5}{8}$ in., the largest number, if not a majority, apparently, being in favor of $\frac{1}{4}$ in. In earlier years the upper limit of preferences was much larger, being $\frac{3}{4}$ or $\frac{7}{8}$ in. Those who approve of the longer radii incline to the wheel-fit idea, and point out that the use of a small radius produces more nearly the effect of a sharp corner in the wear of the wheel flange; that inasmuch as the wheels and rails on curves eventually wear to fit each other, anyhow, were the corner radius of the rail in the first place made more nearly that of the wheel flange fillet ($\frac{5}{8}$ in.) the flange could longer retain its shape. Those who incline to the opposite view explain that when the corner of the rail fits the fillet of the wheel flange there are parts of the wheel making contact with the rail which are not of the same radius; which means grinding action between the surface in contact and hastening of the time when the worn flange will grind against the side of the rail head. While it is true, as those who favor a longer radius claim, that on curved track the flanges will in time wear down the corner of the head to their own curve, still with the small radius such time is necessarily prolonged. It is also to be said in favor of the small corner radius that on straight line, where there is but little tendency to side wear from the wheels, the corner of small radius will keep the wheel flanges from grinding in the fillet and from contact with the side of the rail head for a long time, possibly as long as the rail remains in service, whereas if the corner is of comparatively long radius the wheel fillet will grind against it, and grinding of the flange against the side of the head will take place much sooner. Increase in length of radius of the top corners has also the effect of narrowing the top bearing surface of the rail, and it permits increase in side play of the wheels, as is explained in connection with the side-sloping head. Mr. M. N. Forney has shown that as between a corner radius of $^{11}/_{32}$ in. and one of $\frac{5}{8}$ in. the latter permits $\frac{3}{8}$ in. more side play in the wheels ($^{3}/_{16}$ in. on each side of the track) than the former, on rails gaged the same in either case.

In order to afford the greatest practicable bearing surface for the splice bars the lower corners of the rail head should be rounded but little, and a radius of $^{1}/_{16}$ in. for these corners meets with general approval. The radius for the corners of the rail base should also be small and the sides of the base vertical, so as to afford good bearing surface for the spikes. In some rails of the older designs the top corner and whole side of the base were rounded off to meet a sharp bottom corner which cut the spikes badly. For the further reason that rails with sharp corners are uncomfortable to handle it is desirable to avoid such features in rail design.

As to the shape of the web three forms are used: the web with straight sides; the web with concave sides, the thickness at head and flange being equal, the least thickness coming then at the middle; and the web with concave sides but thicker next the flange than next the head. It is claimed that concave or radial sides work an advantage in rolling, inasmuch as the web, being thinner than either the head or flange, should be thicker next those portions of the rail, which cool more slowly, since it is in those portions of the web that the greatest cooling strains occur. Radii which have been used for this purpose vary from 8 to 30 inches. The web with concave sides and thicker at the base than under the head has largely gone out of use. The object aimed at in this design is perhaps to give the section the appearance of stability, which, of course, is unnecessary. Rails with straight-sided webs have been used extensively, and the difficulties supposed to attend the rolling of the same without undue cooling strains are not generally concurred in. In rails of the same weight, with the same distribution of metal and fillets of the same radius, the web with straight or parallel sides leaves more bearing surface for the splice bars on the under sides of the head than does the web with radial sides.

There seems to be an idea somewhat prevalent that rails are rolled to be used as "rights" and "lefts," and some have professed to understand that the side bearing the rolling-mill brand is intended for the gage side. This is a mistaken idea. Both sides of a rail are supposed to be rolled alike, and if the rolling is properly done the rails may be laid without reference to the branded side. The custom of regarding the sides of a rail with respect to the manufacturer's mark, for any good reason, has been due to carelessness in manufacture, by permitting the rolls to remain in use after they have become unequally worn (as between top and bottom rolls), thus producing a rail of unsymmetrical section. Under such circumstances it is necessary to lay contiguous rails uniformly with respect to the position of the brand, else there will be lip at the joints. In such cases the position of the brand—whether inside or outside—is, of course, immaterial, so long as it is not changed on the same line of rails. It is perhaps needless to remark that if the rails were properly inspected at the mill there would be no necessity for the trouble of sorting them or of changing them from side to side of the track when they are laid. Bolt holes should be drilled, and not punched, lest the web may be fractured. In the old iron rails the bolt holes were sometimes punched and made oblong, so as to allow the rail to expand or contract without straining the splice bolts, but with steel rails provision for this requirement is made by drilling the holes in the rails larger than the bolts and in punching oblong holes in the splice bars.

Not so many years ago the designing of rail sections had become a fad. Most engineers in position to do so felt called upon to get up an independent design, and nearly every road had its own standard section, which would undergo modification as often as changes took place in the personnel of the engineering department. The result was an almost endless variety of designs differing to suit individual ideas, but comprising many collections which were practically identical except for slight and unimportant differences in dimensions. In keeping with this situation each rail manufacturer was obliged to carry a numerous assortment of rolls in stock, and attempts to reduce rail making to desirable standards were confusing. As a matter of record the rail mills at one time had no less than 188 different patterns which were considered standard, and 119 patterns of 27 different weights per yard were regularly manufactured. The situation was investigated by the American Society of Civil Engineers and, in 1893, after deliberating more than three years a committee* of the society reported upon a general type of section and series of sections conforming thereto, for rails varying in weight by 5-lb. increments, from 40 to 100 lbs. per yard. This report was accepted by the society and

*This committee was composed of the following eminent engineers: G. Bouscaren, Foster Crowell, S. M. Felton, Jr., J. D. Hawks, Robt. W. Hunt (Secretary), Geo. S. Morison, E. T. D. Myers, Samuel Rea, H. Stanley Goodwin, Thos. Rodd, A. M. Wellington, Virgil G. Bogue and F. M. Wilder.

recommended to the railway companies for adoption in practice, and the type of section has come to be known as the "American Society standard."

The form of this section is shown by Fig. 13, together with the following constant dimensions for all the sections embraced by the range of weights: Radius of top corners of head, $^5/_{16}$ in.; radius for bottom corners of head and corners of flange, $^1/_{16}$ in.; radius of fillets, $\frac{1}{4}$ in.; radius for top of head and side of web, 12 ins.; fishing angles 13 deg.; distribution of metal, in head 42 per cent, in web 21 per cent, in flange or base 37 per cent. The dimensions which vary with weight of rail appear in Table III. The hight of rail and width of base for each section are equal. It may prove a matter of some interest to state that out of 10 sets of preliminary designs for standard sections submitted by 11 of the 13 members of this committee, independently, in 1891, and previous to any discussion or comparison of views, all were in agreement upon 12 ins. as the top radius and nine were for $\frac{1}{4}$ in. as the top corner radius and for a head with vertical sides. Three sets of designs favored a web with straight sides and five favored concave sides on a radius of 12 ins.; the two other sets of designs offered radii of 9 and 30 ins. Only two of the 10 sets of designs proposed uniform percentages of metal in head, web and

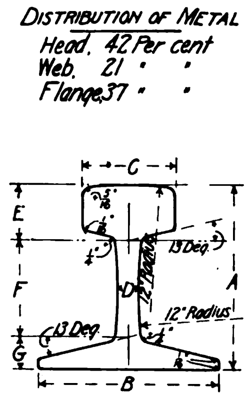


Table III.

	A	B	C	D	E	F	G
Pounds per yard	Hight of Rail	Width of Base	Width of Head	Thickness of Web	Depth of Head	Hight of Web	Hight of Flange
100	5 3/4	5 3/4	2 3/4	9/16	1 45/64	3 5/64	31/32
95	5 9/16	5 9/16	2 11/16	9/16	1 41/64	2 63/64	15/16
90	5 3/8	5 3/8	2 5/8	9/16	1 19/32	2 55/64	59/64
85	5 3/16	5 3/16	2 9/16	9/16	1 35/64	2 3/4	57/64
80	5	5	2 1/2	35/64	1 1/2	2 5/8	7/8
75	4 13/16	4 13/16	2 15/32	17/32	1 27/64	2 35/64	27/32
70	4 5/8	4 5/8	2 7/16	33/64	1 11/32	2 15/32	13/16
65	4 7/16	4 7/16	2 13/32	1/2	1 9/32	2 3/8	25/32
60	4 1/4	4 1/4	2 3/8	31/64	1 7/32	2 17/64	49/64
55	4 1/16	4 1/16	2 1/4	15/32	1 11/64	2 11/64	23/32
50	3 7/8	3 7/8	2 1/8	7/16	1 1/8	2 1/16	11/16
45	3 11/16	3 11/16	2	27/64	1 1/16	1 31/32	21/32
40	3 1/2	3 1/2	1 7/8	25/64	1 1/64	1 55/64	5/8

Fig. 13.—Standard Rail Sections, Am. Soc. C. E.

base throughout the several sections of a set. The average distribution of metal for all the sections submitted stood 42.49 per cent for the head, 20.92 per cent for the web and 36.59 per cent for the base, or practically the percentages finally decided upon. The fishing angles proposed varied from 11 to 14 deg. Six of the 10 sets of designs (7 members) stood for a width of head exceeding $2\frac{3}{4}$ ins. for the 100-lb. rail, the maximum width proposed being $2\frac{7}{8}$ ins. (three designs). Seven sets of designs stood for equality in hight of rail and width of base; one set of designs (two members) made the hight of rail $\frac{1}{4}$ in. less than the base width and two sets of designs made it greater for the heaviest sections (100 lbs. in one case and 90 and 100 lbs. in the other case). The final decision upon $^5/_{16}$ in. as the top corner radius was the result of a compromise to get the two members who favored a larger radius ($^7/_{16}$ in. for rails of 50 lbs. per yard and lighter, and $\frac{1}{2}$ in. for heavier rails) to agree to other features of the proposed sections. Mr. Morison presented a minority report proposing the same width of head ($2\frac{1}{2}$ ins.) for all sections from 50 lbs. and upward, with a uniform distribution of metal at $41\frac{1}{2}$, 21 and $37\frac{1}{2}$ for all weights of rail. His argument was that, owing to interchange of cars, the same wheels must run upon rails of various weights, and in order that uniformity of wear on wheels and rails might obtain, the wearing surface of rails of all weight should be of the same shape and width; and in order that the wheels might properly track down the center line of each rail, the distance between the center line and the gage line should be kept constant on all rails. Mr. Wellington's views on this point admitted that on flat-top rails the application of the principle would be important, but he believed that on rails with a 12-in. top radius the side play in the wheels would naturally cause the treads to wear to a 12-in. radius for a width exceeding that of the widest rail head, so that, "on the principle of the ball-and-socket joint," the worn tread should fit any rail head not over 3 ins. wide. Coming down to fine points, the ball-and-socket principle could hardly apply with rigid axles, but the scheme of constant width of head is somewhat objectionable from another viewpoint, in that, for sections heavier than 80-lbs. the relative depth of the head is increased. The student of rail design should not fail to carefully read the progress report (1891) and final report (1893), with the appended correspondence, submitted by this committee of the American Society of Civil Engineers.

The adoption of rail sections of the American Society standard is on the increase. During the year 1903 rails of this type of section constituted fully 75 per cent of all rails rolled in American mills. The general adoption of a standard type of section should work for economy in several ways: As mills can keep running steadier in dull times, owing to the certainty that the product will find sale when orders begin to come in. and as there is less expense in fitting up rolls and less time lost in changing them, the rails should be made cheaper. Rails should also be made better, because the mills can more frequently avoid rush of work, and constant manipulation of rails of the same form gives a better opportunity to study the physical characteristics of the section and the requirements of rolling it.

Chemical Composition.—Regarding the chemical composition of steel rails it may be said that the impurities inherent in the iron or introduced into the same must be regulated to form a combination of physical properties not usually associated together in such degrees in any other article of manufacture. A railroad rail must be hard, in order to resist flow of metal under wheel pressure, and at the same time it must necessarily possess great toughness, in order to withstand the sudden and severe shocks of ponderous rolling loads. The impurities commonly found in the raw material are carbon, manganese, silicon, phosphorus, and sulphur. The first three are easily within the control of the manufacturer and are desirable, in more or less certain proportions, in order to give the rail its requisite properties; while the other two, as a matter of expense, cannot be entirely eliminated.

Carbon is first in importance among the desirable elements. By itself, alone, up to 1 per cent, it increases hardness and tensile strength but decreases the ductility or toughness. It was formerly used in proportions varying from 0.25 to 0.50 per cent, but late years the tendency is to higher carbon, in order to effect gain in hardness required to meet the increased wheel pressures. The properties of the metal also depend largely upon the manner of mechanical treatment, as frequent rolling at comparatively low temperatures will produce a fine grain and compact structure which will improve the wearing qualities of the rail, whatever amount of carbon is used, and the same treatment will make up, to a degree, the toughness lost by the use of higher carbon. Generally speaking, 0.40 per cent or under, of carbon, is now considered low; 0.40 to 0.55 per cent, medium;

and above 0.55 per cent, high. The most common practice, perhaps, is to use 0.45 to 0.55 per cent of carbon, but even as high as 0.70 per cent is sometimes used. It is deemed to be safe practice to increase the carbon with increase in weight of rail, for the larger rail is stronger, and, as less work is done upon it under the rolls, the hardness due to the extra carbon is needed to make up for loss in compactness of structure, in order that the wearing qualities may not be impaired. The proportion of carbon must also depend somewhat upon the percentage of phosphorus present: the higher the phosphorus the lower the allowance of carbon, and vice versa. A uniform specification for all grades of steel is not considered good practice.

Manganese is necessary to take up the oxides of iron formed while the metal is in the molten state, the products of the combination passing off in the form of slag. It also tends to prevent the formation of oxides while the heated metal is being worked into shape. In sufficient quantity it assists toward a more uniform distribution of the carbon through the iron. It facilitates the chemical combination of the carbon with the iron, at high temperature, and tends to prevent separation into graphitic carbon or graphite as the iron cools down. If not used to excess it imparts strength and toughness. If the iron is low in carbon the effect of manganese is similar to that of carbon alone, but diminishes the ductility in less degree; it may therefore replace carbon to some extent. It is considered an effective antidote for sulphur. When used in high percentages it has the effect of making the rail hard and coarsely crystalline, and its tendency is to brittleness, much the more as it exists in unnecessary quantity. Its use varies, according to circumstances, from 0.70 to 1.40 per cent.

Silicon is useful in that it acts as a flux, and, like manganese, and in the same manner, tends to prevent injury by oxidation of the iron. In this way it prevents the formation of blow holes, and imparts to the metal a solid structure of small crystallization. When of just sufficient amount it gives added toughness, but any increase beyond this tends to brittleness. It has a hardening effect and, to a limited extent, may replace carbon. Its use ranges from .10 to .20 per cent.

Sulphur and phosphorus are both objectionable elements, but difficult to eliminate entirely from the metal. They perform no useful combinations in any way not more satisfactorily obtained by other elements, and must be kept low, sulphur generally not to exceed .07 per cent, and phosphorus not to exceed .085 per cent. Rails high in either cannot be so high in carbon, as already stated. Sulphur produces red-shortness or hot-shortness (brittleness at high temperature), thus imparting to the metal a tendency to crack and form seams in rolling. Phosphorus increases the size of the crystallization and causes cold-shortness, making the metal hard and brittle and liable to crack or break in cold weather. It should be said, by way of parenthesis, however, that for steel very low in carbon a small percentage of phosphorus (not to exceed .04 per cent) is claimed to be beneficial, in that it seems to add strength to the metal. In the metallurgy of iron and steel there is apparently no rule which holds good throughout the range of combination of any one of the alloys, and this fact in respect to phosphorus would seem to be only one of the exceptional cases.

Traces of copper are frequently found in rail steel, and sometimes it runs as high as 0.80 per cent, although specifications do not usually require it or place limitations upon the percentage used. It was formerly understood that the tendency with copper was to produce red-shortness, but recent experiments (by Stead and Evans) made known to the Iron and Steel Institute, and others, are offered to prove that between 0.5 and 1.3 per cent copper has no deleterious effect on either the hot or cold property of steel. In small quantities it slightly raises the tenacity and elastic limit, without tendency to brittleness, but reduces the toughness, although this effect is not pronounced when the quantity is small.

Oxide and slag generally exist to the extent of 0.10 to 0.12 per cent, but are not usually determined. When present in quantity sufficient to render the metal spongy the wearing qualities of the metal are impaired. In the molten metal the tendency of these constituents is to float to the top of the ingot, and formerly it was the practice in the mills to cut off and reject sufficient material from the top part of the ingot to discard these impurities. In later practice, however, owing to the cheap price of rails and the rapid handling of the metal, this has not been done unless required by the specifications. Authorities on steel manufacture recommend that this precaution should be insisted upon, for they say that the upper portion of an ingot in cooling intercepts considerable quantities of gaseous matter. These are retained in small spherical cavities which roll out flat during the blooming process without welding together at the sides, thus leaving cracks in the metal.

In a general way rail steel, exclusive of the iron, has about the following range of composition:

	Limits.	Most General Practice.
Carbon,	.30 to .70 per cent	.45 to .55 per cent.
Manganese,	.70 to 1.40 per cent	.80 to 1.00 per cent.
Silicon,	.10 to .20 per cent	.10 to .15 per cent.
Phosphorus,	not to exceed .10 per cent	.06 to .085 per cent.
Sulphur,	not to exceed .07 per cent	.05 to .07 per cent.

Chemical specifications, however, are considered only an approximate guide, because much depends upon the mechanical and heat treatment of the metal during the process of manufacture. During late years chemical specifications have not been considered as highly important as they once were. More stress is now being laid upon the production of rails to meet certain tests of strength and stiffness, or on a guarantee of serviceability for a stated period, than upon the chemical composition. It has come to be the custom with many roads to leave the chemical composition, within wide limits, or entirely, to the discretion of the manufacturer.

Physical Properties.—The wearing qualities of a rail are dependent in large degree upon the fineness of the grain and the compactness of the metal in the head. In order to produce rails of this character and secure the best results it is necessary that the metal shall pass the rolls at a comparatively low temperature, and a relatively large number of times; that is, meet with a small reduction at each pass. In fact, the consensus of expert opinion now maintains that the question of chemical composition is subordinate to the physical treatment of the metal. It is a fact well established that equally good service has been obtained from rails with widely varying chemical components, not excepting the carbon. When steel cools from a high temperature without being worked it takes on a coarse crystalline structure. The higher the initial temperature and the slower the cooling, the larger the crystals and the coarser the grain of the metal; and, as above intimated, coarse-grained steel is inferior from the point of view of rail wear. If the metal is frequently worked while cooling from the high temperature the crystallization into large grains is prevented, but if the work ceases before the heat has fallen to a certain point known as the "critical temperature," crystallization will take place until the critical temperature is reached; in cooling below this critical temperature there is no further crystallization or perceptible change of structure. It is therefore desirable to continue working the metal until the temperature has dropped nearly to the critical point. Relatively speaking, work on the metal at high temperature merely changes the form of the mass without changing the structure. If the work is stopped before the critical point is reached there will be some crystallization, the amount or degree of which will depend upon the range of temperature through which the metal cooled in an undisturbed condition. This critical temperature for ordinary rail steel is about 1300 deg. F., as already shown. At temperatures below the critical point, or, at all events, much below that point, it is undesirable to do work on the metal, for the structure cannot be changed in any desirable respect and there is possibility of distorting the crystals and producing permanent strains in the metal, which results in brittleness. If work is done upon the metal at successively lower temperatures until it cools to the critical point the crystallization becomes smaller and smaller and the result is a metal of fine granular structure best fitted to stand the abrasive action of heavily loaded car and locomotive wheels. The bad effects of finishing steel at high heat seem to increase with increase of carbon and other impurities; in other words the proper regulation of the heat treatment permits the use of higher carbon than otherwise. The foregoing seems to be the gist of the question of producing good wearing rails.

It is a trite saying that the wearing qualities of rails made during late years, particularly the rails of heavy section, have been disappointing; that they do not compare with the service obtained from the 50-lb and 60-lb. rails rolled about the year 1880. The reasons explanatory of this experience have been discussed until the situation is quite generally understood. Making due allowance for the effect of the largely increased wheel loads and train speeds, the currently accepted views of the situation may be summed up briefly in the statement that competition and the desire of the railway companies to purchase rails at the lowest possible price forced the manufacturers to resort to quicker and cheaper methods of handling the metal in process of rolling, with the result that the rails were finished at a too high temperature to obtain the benefits of the rolling action on the steel, or the "working" of the steel, as it is called. In course of time the competition largely disappeared and the manufacturers fixed their own price for rails, but the quality of the metal was not improved. More in detail, it may be explained that rails are now run or, according to Mr. D. J. Whittemore, "squirted" through the rolls in nine to eleven passes from the bloom, at a speed of 900 ft. per minute, and finished (or nearly finished) at temperatures of 1800 to 2000, and even 2200 deg. F., whereas in former practice the rail was given 13 to 15 passes after blooming, at a speed of 400 ft. per minute, and finished at a temperature of 1300 to 1600 deg., or, say, about 500 degrees cooler. And then, in the former practice the metal was permitted to cool and consolidate itself after each operation of casting the iron from the furnace, blowing in the converter, and blooming the ingot; while now, with the modern appliances in service, the melted metal is handled by direct processes and so rapidly that it does not get a chance to cool or come to rest molecularly, from the time it is cast from the furnace until the finished rail is run upon the hot bed to cool. In fact the process is hastened at every stage. The furnace is hard driven in smelting the ore and the metal is blown more rapidly and in larger quantity in the converter. It is supposed that in either case less opportunity is given for the thorough combination* of the various chemical elements. The old method of permitting the metal to cool between the successive steps of manufacture is believed to have improved the molecular structure or crystallization of the metal, and it gave opportunity to carefully examine the blooms for flaws, which, if discovered, were chipped out with hammer and chisel. In present practice 16x18-in. ingots (the average size, some being as large as 20x 24-ins. on the base) are rolled down to 8x8-in. blooms in 11 passes, as against reducing 14x14-in. ingots to 7x7-in. blooms in 13 passes, in the old practice, or of slowly hammering the ingots into blooms, as in the still earlier practice. While there is more reduction from ingot to bloom in present practice than formerly, the rate of reduction is faster per pass through the rolls, not considering the higher speed of the rolls. The bloom of ordinary length will now roll three or four 30-ft. rails in one piece, or a rail 90 to 120 ft. long. In some mills the ingot is long enough (4 or 5 ft.) to roll into a 5-rail bloom, which is then cut in two, one piece making three, and the other two, 30-ft. rails. Taking into consideration the increased weight of rails the reduction from bloom to rail at the present time is just about the same as formerly, but, as above shown, the rate of reduction is much faster, as regards both diminution of section per pass through the rolls and the actual speed in traveling through the rolls. All this haste leaves the rails hotter at the finish.

On the part of the manufacturer it is desired to handle the metal at high temperature, so that it will roll easier, or, in a measure, compensate for the extra work imposed upon the rolls by the faster rate of reduction of the metal at each pass and the higher speed at which the roll train is driven. Although the change from the old to present methods and the effects thereof are well understood by both consumer and manufacturer, there is no disposition on the part of the latter to return to lower initial temperatures or to slower rolling. To start the rolling at a relatively low temperature would throw more work upon the rolls, and to reduce the speed of the machinery would decrease the output of the mills. As either plan of improvement would increase the cost of the rail, the manufacturers have not been inclined to adopt it.

The agitation among railway engineers over poor rail metal and the demand upon manufacturers to produce better wearing rails induced the latter to increase the proportion of carbon and other hardening elements to as large percentages as they thought could be used without making the rails brittle, but these chemical changes did not give the desired results. For many years railway engineers had been demanding of the mill men that rails should be rolled at lower temperatures, and eventually some of the railway companies began to introduce into their specifications what is known as the shrinkage allowance clause, requiring that on leaving the rolls at the final pass the temperature of the rail should not exceed that which requires a certain shrinkage allowance at the hot saws, and that no artificial means of cooling the rails should be used between the finishing pass and the hot saws. The idea in fixing the

*Somewhat in this connection it is a significant fact, discovered through microscopical examination, that rail steel is not a homogeneous material. Certain constituents formed by the chemical union of two or more elements separate out from the mass as it cools down, leaving the steel in some degree a mechanical mixture. Whether this condition may result wholly or in part from a too hasty manipulation of the metal in the molten state does not appear to have been investigated.

shrinkage allowance was that the railway companies, through their inspectors, could thereby control the temperature at the last pass. The plan of rolling from a lower maximum temperature was not in favor with the mill men, because the metal would be harder to roll, and some difficulties might be introduced which would either reduce the output or require heavier machinery, as above explained. It was therefore represented that if the metal was brought to the desired temperature before making the last pass through the rolls, all the benefit that railway men were looking for could be accomplished without reducing the output. This plan was put to trial. During December, 1900, the Carnegie Steel Co. introduced at its Edgar Thomson Works what is known as the Kennedy-Morrison rail finishing process, whereby the rail, after the next to the last pass, is held on skids until it can cool to a point from which it will make the last pass at a desirably low temperature. The details of the process are described below.

The Kennedy-Morrison Process.—The process known as the Kennedy-Morrison method of rolling rails consists in allowing the rails to accumulate on a cooling table located just in advance of the finishing rolls, where they are held for a short interval of time to regulate the heat condition of the metal for the last reduction. The bloom is first passed forward and backward through five passes in the roughing rolls and then run to the intermediate or "short" rolls, where it receives five passes in the same manner. The partially rolled rail is then run upon the special cooling table, being laid on its side with the head against the flange of the rail next ahead. Four to six or more rails are held on the cooling table at one time, and as each rail is drawn on it pushes over all the rails before it, a rail being taken off the far side and sent through the finishing rolls as each one is drawn on the front side. The idea in placing the rails head to base is that the flange being thinner tends to cool quicker than the head, but since it is in contact with the head of the rail lying next behind it will receive heat therefrom, so that the heat in heads and flanges is maintained more nearly at a balance than would be the case if the rails were placed workwise or were allowed to cool separately. And then as each rail arrives at the outside of the table its head lies exposed (but the base does not) while it awaits its turn to enter the finishing pass. The difficulty of cooling down the head to a desirable temperature without getting the base too cold for working is therefore to some extent overcome. The rails enter the cooling table at a temperature of 1750 to 1900 deg., and are held 45 to 90 seconds, the temperature meanwhile falling to somewhere about 1500 deg., when they are put through the finishing pass. As this method of rolling does not interfere with the rapidity or continuity of action of the mill the production is not diminished.

This departure in rail rolling has been a subject of much discussion, and for a time railway men seemed to rest under the impression that they had gained their point. While it is thought that rails held to cool before finishing have shown some improvement in wearing qualities it is an open question whether the process is as effective as direct rolling from a lower maximum temperature to reach the same temperature at finishing. The practice of holding the rails for the last pass has no particular regard to the initial temperature of the ingot, or the temperature when rolling starts on the bloom. The criticism of the metallurgists is that the rails may be allowed to cool undisturbed through such a large range of temperature during the time they are held for the last pass that the work performed in the final reduction has only a superficial effect. The amount of reduction at this last pass is 5 to 10 per cent. In this way 90 to 95 per cent of the reduction is carried on at relatively high temperature, and only 5 to 10 per cent at the lower or "finishing temperature." It is explained that this final working does not break up the granular structure deep enough; that it toughens the steel only "skin deep," so to speak, producing a case-hardening effect on the exterior, but leaving a coarsely granular structure in the interior; that not enough work is done after the cooling, and that much better results might be obtained if the material was held for cooling at an earlier stage in the rolling process; some suggest immediately after the bloom is cut off, so that a very large reduction may take place while the metal is cooling down to a point near the critical temperature; a reduction sufficient to work the steel thoroughly to the center. Another principle of rail manufacture in this same connection is that the rolling of rails direct from the ingot produces better structure than rolling from reheated blooms, the reason being that the bloom goes through the roll train at a lower temperature than is the case in a reheating mill where the bloom is rolled at a high temperature to the final pass and is then held a sufficient time to obtain the desired shrinkage allowance. Mills built to roll direct are of heavier construction, with rolls which will stand the harder work of the cooler rolling. In this country there are only a few mills that roll rails in this manner, but abroad the practice is more generally followed.

From the foregoing it is easy to see how the wearing qualities of the rail may be greatly affected by the rail design. As the desirable end is to have the rail head obtain a large amount of work (large reduction slowly performed) from the rolls at relatively low heat it is apparent that a rail of the best structure cannot be rolled with a deep head and thin flange, because on such a design the rail head must be finished at a comparatively high heat in order to avoid working the more rapidly cooling flange after it has become too cool. In order to hold the flange at a proper temperature for rolling to the finish the tendency is to heat the bloom too high to produce a head that is physically hard and compact. On these grounds there has been some agitation for a change in the section of the heavier rails—85 lbs. per yd. and upwards. It is proposed to increase the thickness of metal in the flange in order to carry the heat longer and permit working the head at a lower temperature.

An interesting modification of one of the standard sections, although not primarily to improve the mill treatment of the metal, has been made by the Grand Trunk Ry. In order to increase the bearing surface of the rail on its cedar ties this road has widened the base of the 80-lb. section 1 inch and thickened it by adding $\frac{1}{8}$ inch of metal to the bottom thereof. The modified section is the A. S. C. E. standard 80-lb. section in every respect except for the changes stated, which make the section 6 instead of 5 ins. wide and $5\frac{1}{8}$ instead of 5 ins. high. The additional metal increases the weight to 90 lbs. per yd.

Straightening and Gagging.—After the rail receives its final pass at the rolls it is sawed off 5 to 7 ins. longer than the intended final length, to allow for contraction in cooling, and then it is run through a cambering machine and curved upward 3 to 16 ins., according to the temperature and depth of head. It then goes to the hot bed, where the rails are spaced 6 to 8 ins. apart. The behavior on the hot bed is described under "Rail Design." After the rail has cooled, whatever crookedness exists must then be removed under the straightening press. The machinery consists of an anvil, on which are placed supporting blocks for the rail, and a plunger which rises and falls vertically over the anvil about 60 times per minute, being operated by a revolving shaft to which a heavy fly wheel is attached. The rail is moved lengthwise over the supports to bring each crooked portion under the plunger, which does its work through a die or fuller called a "gag." This tool has a slightly rounded face and is applied to the rail at points indicated by a man who does the sighting. Long curves in the rail are straightened by several slight bends. If the rail has been too heavily cambered it must be straightened by hitting it with the gag every 18 ins. or 2 ft. over its entire length. If the supporting blocks are spaced too close or the blows of the plunger administered too severely the rail will be sharply bent or kinked and the head indented. These indentations and bends are known as "gag marks," and when they become pronounced the surface of the rail is uneven and imparts a jolting motion to the cars. Gag-marked rails are difficult to maintain in surface, because the vibration or rough running of the wheels causes them to pound down the track. Rails heavily gagged are more liable to break at the indented points than elsewhere, owing to the permanent set in the metal due to the cold straightening. The evil effects from gagging may be largely avoided by designing the section and working the metal to require as little cambering as possible, and then looking carefully to the spacing of the anvil blocks or supports. Mr. P. H. Dudley's specifications require that the anvil supports for 60 and 70-lb. rails shall be spaced at least 3 ft. apart between centers; for 75 and 80-lb. rails, at least 40 ins. apart, and for 100-lb. rails at least 44 ins. apart.

Specifications.—Rail steel may be made by either the Bessemer or the open-hearth process, but practically all the rails in service in this country are of acid steel made by the Bessemer process. In §197 of Supplementary Notes there is a brief explanation of the different ways in which rail steel may be made, together with some account of the proposed deviations in this direction and in rail design.

While some railway companies purchase rails under chemical specifications of their own, it may be said that in most cases the technical conditions of manufacture are left to the discretion of the manufacturer. The purchaser's interests are then secured either by a stipulation that certain tests shall be made to determine whether the metal has the desired physical properties, or by exacting from the maker a guarantee against breakage and unusual wear for a service period of five years. Rails which fail within this period are replaced by the manufacturer, and usually he is required to pay the railroad company an indemnity of $1.00 for each defective rail sent back, this to cover the expense of removing it from the track, handling, etc. A synopsis of American rail specifications prepared by the American Section of the International Association for Testing Materials, in 1900, referred to 11 different sets of specifications drawn by railway companies, while 155 roads and their branches used rails made to manufacturers' specifications. The specifications of the Pennsylvania R. R. in force at that time (carbon 0.30 to 0.50 per cent) were used on 19 roads. Many of the railways specify only the carbon, silicon and phosphorus limits, leaving the manganese and sulphur percentages to the maker. It is sometimes specified that the test pieces for analysis shall consist of bars ¾ in. wide and about 10 ins. long, each to be taken from the web of a rail made from each charge or blow. More frequently, however, the analyses are made on drillings from small test ingots taken from each blow, the manufacturer furnishing the inspector daily with carbon determinations of each blow and a complete analysis representing the average of the other elements which the steel contains.

The chemical specifications of the manufacturers conform to, or pretty nearly to, one or the other of two sets of specifications now recognized as standard in accordance with geographical and commercial conditions. Thus, for instance, available ores west of the Allegheny mountains are higher in phosphorus than eastern ores, and this fact exercises an important modification on the proportion of carbon. In the Scranton and Bethlehem districts the New York Central & Hudson River R. R. specifications are considered standard and may be taken as typical of a large percentage of the rails made from eastern ores. In these specifications there is a progressive increase of carbon and manganese with increase in weight of rail. For 65-lb. rails the carbon content is .45 to .55 per cent, the rails to be rejected if the carbon is below .43 or above .57 per cent; for 70-lb. rails, carbon .47 to .57 per cent, the rails to be rejected if the carbon runs below .45 or above .59 per cent; for 75-lb. rails, carbon, .50 to .60 per cent, with allowable limits of .48 to .62 per cent; for 80-lb. rails, carbon .55 to .60 per cent, with allowable limits of .53 to .65 per cent; for 100-lb rails, carbon .65 to .70 per cent, with allowable limits of .60 to .70 per cent. In these specifications the silicon runs from .15 to .20 per cent, sulphur not to exceed .069 per cent and phosphorus not to exceed .06 per cent, for all weights. For 65-lb. and 70-lb. rails the manganese runs from 1.05 to 1.25 per cent; for 75-lb. and 80-lb. rails, from 1.10 to 1.30 per cent; and for 100-lb. rails it runs from 1.20 to 1.40 per cent.

In the specifications of the western rail mills the carbon content for various weights runs as follows: 50-lb. to 60-lb. rails, .35 to .45 per cent; 60-lb. to 70-lb. rails, .38 to .48 per cent; 70-lb. to 80-lb. rails, .40 to .50 per cent; 80-lb. to 90-lb. rails, .43 to .53 per cent; 90-lb. to 100-lb. rails, .45 to .55 per cent. The phosphorus must not be over .10 per cent and the silicon not over .20 per cent, for all weights. For 50-lb. to 70-lb. rails, manganese runs .70 to 1.00 per cent; for 70-lb. to 80-lb. rails, .75 to 1.05 per cent; for 80-lb. to 100-lb. rails, .80 to 1.10 per cent. Mr. Robt. W. Hunt's specifications, also much used for rails manufactured west of the Allegheny mountains, are lower in phosphorus and higher in carbon than the standard of the western rail mills, being about intermediate between the two standards just referred to, and running as follows: Carbon, .43 to .51 per cent for 70-lb. rails, .45 to .53 per cent for 75-lb. rails, .48 to .56 per cent for 80-lb. rails, .55 to .63 per cent for 90-lb. rails, and .62 to .70 per cent for 100-lb. rails; silicon not below .10 per cent; phosphorus not to exceed .085 per cent; manganese and sulphur left to the makers.

The rail specifications of the Pennsylvania R. R. provide that if the phosphorus exceeds .07 per cent the carbon shall not be less than 0.40 nor more than 0.55 per cent, and the manganese not higher than 1.00 per cent. If the phosphorus is .07 per cent or less the carbon shall not be less than 0.45 nor more than 0.60 per cent, and the manganese not more than 1.20 per cent. The phosphorus must not in any case exceed 0.10 per cent.

For ascertaining the physical properties of the metal the general practice with the American roads is to use the drop and bending tests. The standard weight or "tup" of the drop testing machine weighs 2000 lbs. and the striking face has a radius of about, or not to exceed, 5 ins. The test rail is usually placed workwise—but sometimes with either head or base upward—on solid supports 3 or 4 ft. apart. Some specifications require that the anvil block, of which the supports are a part or to which the supports are secured, shall weigh at least 20,000 lbs. The hight of drop varies with different railways from 16 ft. for 60-lb to 75-lb rails, to 20 ft. for 70-lb. and 75-lb. rails, and 20 to 24 ft. for 80-lb. rails, on supports 3 ft. apart, all the way up to 20 ft. for 100-lb. rails, on supports 4 ft. apart. In some cases a drop of 16 ft., and in other cases 18 ft., is specified for 75-lb. rails on supports 4 ft. apart, while in still other cases a drop of 20 ft. is specified for all rails heavier than 70 lbs. per yard, on supports 4 ft. apart. The specifications of the Philadelphia & Reading Ry. require a drop of 18 ft. for rails weighing 70 lbs. per yd. and under, and 23 ft. for rails heavier than 70 lbs. per yd., solid iron or steel supports 3 ft. apart (between centers) in all cases. The test piece is placed with either head or base upwards, or upon the side, and in this respect the same practice is followed by the N. Y. C. & H. R. R. R.

The standard drop test recommended by the American Railway Engineering and Maintenance of Way Assn. requires that the test rail shall lie head upward and that the supports shall be placed 3 ft. apart for all weights of rails. The hight of drop is 15 ft. for rails weighing 45 to 55 lbs. per yd., inclusive; 16 ft. for rails 56 to 65 lbs., inclusive; 18 ft. for rails 66 to 75 lbs., inclusive; 20 ft. for rails 76 to 85 lbs., inclusive; and 22 ft. for rails 86 to 100 lbs., inclusive. Various specifications require that the test rail or butt must not be longer than 6 ft. or shorter than 4 or 4½ ft., for supports 3 ft. apart. It should be cut from that part of the rolled product which has come from the top of the ingot, and the report of the drop test should state the atmospheric temperature at the time the test was made. To guard against brittleness, the specifications of the Russian government railways, previous to 1899, provided that drop tests might be carried out on rails at freezing temperatures.

In order to pass the test the butt is supposed to stand up under one blow from the falling weight without breaking. The specifications of the Pennsylvania R. R. require that the test pieces from 100-lb. rails must not deflect more than 3¾ ins. from the first blow. The specifications of the Louisville & Nashville R. R. require that the butt must not bend more than 6 ins., and, upon reversal, must stand, without breaking, a blow on the convex side from the weight (2000 lbs.) falling through half the standard hight, which is 16 ft., 20 ft., and 24 ft. for 58¼-lb., 70-lb. and 80-lb. rails, respectively, supports placed 3 ft. apart in all cases. A test is usually made on a butt from each heat or blow of the converter, but some specifications require that if the quantity of metal converted exceeds 9 tons there shall be two tests. The specifications of some roads require that 90 per cent of the butts must stand the test without breaking, and in addition to this it is sometimes required that the metal in the inch under greatest tension must show an elongation, at or before breaking, of 4 to 5 per cent. For measuring this extension an inch scale about 6 ins. long is prick-punched on the under side (head or base, as the case may be) of the test rail, opposite the point of impact, before testing, and if the rail does not break or bend sufficiently to develop the required stretch at the first blow the test is repeated until it does. In the largest practice, however, it is specified that if any test piece should break under a single drop of the tup, another butt from a rail of the same heat may be tested, and if it fails all the rails of that heat shall be rejected; but if the second test stands, still another butt must be tested, and the rails shall then be accepted or rejected according as this third test piece proves a success or a failure. This is the standard specification of the Am. Ry. Eng. & M. W. Assn. It is seen that by this method a single test may determine the result of a heat, but in still another way of drawing specifications it is provided that two butts out of three must stand the test in order that the rails shall be accepted. The specifications adopted by the American Society for Testing Materials provide that one drop test shall be made on a butt not longer than 6 ft. selected from every fifth blow of steel, the rail to be placed head upwards on the supports. If any rail fails to stand the test, second and third tests may be made on other rails from the same blow of steel, and if both of these meet the requirements all the rails of the five blows shall be accepted; if either fails, all the rails of that heat are to be rejected. Should the rails from the tested blow be rejected, the preceding and succeeding blows shall be tested and the rails of each of these blows accepted or rejected according to the same specifications. If the rails of either of these two blows shall be rejected similar tests may be made of the previous or following blow, as the case may be, until, if necessary, the entire group of five blows is tested.

The falling weight or drop test subjects the metal to sudden and severe duty, such as the rail must stand in actual service, and is a check on brittleness. It is therefore to some extent a measure of the toughness, especially when the elongation requirement is introduced, but the special test for toughness is the bending test. This test requires that a bar ½ in. square and 18 or 20 ins. long, drawn at one heat, by hammering from a test ingot 2½ or 3 ins. square in section and 4 ins. long, shall be bent cold to an angle of 90 deg. by the blows of a sledge, without breaking. Two test ingots are cast, usually from the steel in the first and last ingots poured from the same heat. The usual requirement is that both bars drawn from these two ingots must stand the test, but should one of them fail a third bar may be taken from the same ingot, and if this stands it may be accepted in lieu of the failed one. The bending test of the Cambria Steel Co. requires that two test ingots shall be taken from the middle portion of an ingot of each heat while the ingot is being bloomed, and if one bar ½ in. square forged down at one heat stands the test the rails of that heat shall be accepted; if the bar fails, a second one shall be prepared, and if this one fails the heat shall be rejected.

In this country the testing of rail metal for tensile strength is not in general practice, but test pieces from rail steel of good quality will usually show an elastic limit of 55,000 to 65,000 lbs. per sq. in. and an ultimate strength of 110,000 to 120,000 lbs. per sq. in., at breaking, with an elongation of 12 to 15 per cent in a specified length—usually 8 or 10 ins—and a modulus of elasticity of 29,000,000 to 30,000,000 lbs. In this country no tests for hardness are imposed, but the physical hardness can be quite closely determined from the chemical hardness—that is, by the amount of carbon and phosphorus present. Some attempts at measuring degrees of hardness have been made by observation of the indentations on the rail of loaded knife-edges of hardened steel, but the use of such tests and others of different character does not seem to have passed the realm of experimentation.

As to the process of manufacture specifications, as a rule, have fewer requirements than formerly. In order to equalize the heat it is usually required that ingots shall be kept in an upright position in the heating pit, or until rolled, or, in any case, until the interior of the metal has had time to solidify. The shrinkage on the upper side of ingots which lie horizontally is liable to form a "pipe" or split in the interior of the rail. "Bled" ingots, or ingots from the interior of which the liquid steel has been permitted to escape, are always supposed to be rejected. Reference has already been made to the practice of discarding ojectionable material from the top of the ingot, and it is usual to specify that spongy material shall be cut from the ends of blooms. Many years ago hammered ingots were preferred, owing to the beneficial effects from that manner of working the metal, but owing to the demand for cheaper rails the practice had to be abandoned; it is still in vogue to some extent in Great Britain.

The specifications as to branding usually require that the name of the maker and the year and month of manufacture shall be rolled in raised letters on the side of the web and that the heat number shall be stamped on each rail, usually on the side of the web and in such position that it will not be covered by the splice bar. In addition to these some specifications require that the weight of the rail and the initials of the railroad shall be rolled on the web.

With a view to control the finishing temperature, it is usual to include in rail specifications a clause which limits the amount of shrinkage that may take place in the rail from the time it is cut at the hot saws until it reaches the normal temperature. For 30-ft. 85-lb. rails the Pennsylvania R. R. specifies $5\frac{1}{2}$ ins. and for 100-lb. rails $5\frac{5}{8}$ ins. The Am. Ry. Eng. & M. W. Assn. recommends that "The number of passes and speed of train shall be so regulated that on leaving the rolls at final pass the temperature of the rail will not exceed that which requires a shrinkage allowance at the hot saws of .... ins. for 85-lb. and .... ins. for 100-lb. rails, and no artificial means of cooling the rails shall be used between the finishing pass and the hot saws." The practice adopted at the Edgar Thomson Works of the Carnegie Steel Co. for rails of 75-lb. to 100-lb. section is to allow a shrinkage of $5\frac{3}{8}$ ins. for 30-ft. lengths and $5\frac{3}{4}$ ins. for 33-ft. lengths. This is accomplished by holding rails of the various sections different lengths of time on the cooling table before they pass through the finishing rolls. In order to meet the intentions of those who would wish to control the finishing temperature there should be a time qualification in this specification, for the mill conditions, such as the distance of the saws, might permit the rail to cool down a good deal while passing from the rolls to the saws, so that the shrinkage after leaving the saws would be a great deal less than the shrinkage after the finishing pass, which is really the measure of the finishing temperature. Twelve seconds after leaving the finishing rolls is considered the proper time limit for cutting the rails to length.

It is well enough to bear in mind that control of the finishing temperature is not necessarily a control of the heat treatment throughout the rolling process. Although, with a proper time limit, the shrinkage allowance may control the temperature at the finishing pass, it does not put a check upon the practice of rolling the metal very hot and then holding it to cool down just in advance of the last pass. It may not, therefore, serve as a good index of the structure of the metal. The specification of the Philadelphia & Reading Ry. in reference to heat treatment would seem to be drawn with this liability in view. It is as follows: "The temperature of the ingot or bloom shall be such that with rapid rolling and without holding before or in the finishing passes or subsequently, and without artificial cooling after leaving the last pass, the distance between the hot saws shall not exceed 30 ft. 6 ins. for a 30-ft. rail, or a proportionate distance for other lengths."

Other specifications are referred to in connection with the following matter on rail inspection.

Rail Inspection.—The proper place to inspect rails is, of course, at the mill, as then if bad rails appear further manufacture of the same may be prevented at once. The inspector representing the purchaser is supposed to see that the proper physical tests are made, if the rails are bought on that basis, and that the finished material conforms to the specifications. Facilities for these purposes are furnished by the manufacturer and the inspector is granted free entry through the works. Each rail should be carefully examined for flaws, crookedness, kinks and indentations from gagging, and to see that it conforms to the templet of the standard cross section and that uniformity of section is maintained. New rails should not camber in the least, since if they do the joints in the track will naturally dip; on the contrary, a small amount of sag or "back sweep" is not objectionable, as in that case the spring in the rail assists the splice bars to hold the joint in surface. The inspector must, of course, have a "good eye," according to the meaning of the term among trackmen. It is quite generally the practice with railway companies when purchasing quantities of rails to employ experts who make a business of rail inspection, charging for their services according to the quantity of rails inspected, five cents per ton being a figure quite frequently paid. Some of the large railway systems have their own expert, who fills the established office of "rail inspector," and some railways send their roadmasters or engineers in the track department to the mills to inspect their rails.

Rails are bought and paid for on the actual weights. It is usual to permit a variation of 1 per cent in the weight of individual rails and ½ of one per cent in the weight of an entire order. To ascertain how individual rails are running some specifications require that a rail shall be weighed every hour, as the rolling proceeds. It has been customary to allow a variation of $^1/_{32}$ in. over and $^1/_{64}$ in. under the standard hight of section, although some railway companies put the limit at $^1/_{32}$ in. either way (Southern Ry.) and others put it at $^1/_{64}$ in. either way, the latter being the practice with the Michigan Central and Wabash roads. In this respect the specifications of the New York Central & Hudson River R. R. provide as follows: "A variation not exceeding $^1/_{64}$ of an inch of excess in hight may be permitted in a delivery of 10,000 tons of rails of any section, after which the rolls must be reduced to the standard hight for such section."

The hight of rails of the same section varies with the wear of the rolls, and in order to make smooth joints when spliced, rails which vary even as little as the limits permit should not be mixed together in the shipments. For instance, a rail which measures $^1/_{32}$ in. over the standard hight of section would not make a smooth joint with one measuring $^1/_{64}$ in. under the standard. With a view to the requirements of the service the gaging of the vertical dimensions of the rail section should be controlled by the type of joint splice to be used. With ordinary angle-bar splices the important vertical dimension is the depth of head rather than hight of section, because the manner in which the running surfaces will match at the joint depends upon the thickness of metal above the top edges of the splice bars. With joint splices which engage the bottom of the rail flange it is obviously necessary that the total hight of the rails should be uniform or within limits. It is customary to permit a variation of $^1/_{16}$ in. in width of base. The requirements as to base width stand in relation to the use of tie plates, which are punched for the spikes a fixed distance apart.

As the fit of the splice bars should be maintained as nearly perfect as is practicable no misfit of the fishing templet is allowed. The allowable variation from specified length is ¼ in. This is measurable without temperature correction at 60 deg. F. Rails should be sawed square at the ends, but it is customary to permit a variation of $^1/_{32}$ in. between length of head and base. It is usual to accept 10 per cent of the order in lengths shorter than standard, varying by even feet down to a length specified, which, in largest practice, is 24 ft. for 30-ft. rails. This minimum length varies with different railways from 22 to 27 ft., and some specifications require that the average length of short rails shall not fall below a specified length; as, for instance, the minimum length acceptable with the Chicago, Burlington & Quincy Ry. is 24 ft., and the average length of the short rails must not fall below 26 ft. The percentage of short rails acceptable is sometimes put as low as 4 per cent. The Am. Ry. Eng. & M. W. Assn. recommends that 10 per cent of the order may be accepted in lengths shorter than standard (33 ft.) and that the minimum length acceptable shall be 27 ft. Specifications provide, of course, for the spacing of the bolt holes, requiring that they shall be drilled accurately and left without burrs. The burrs on the rail ends made by the saw should be chipped and filed off, particularly where they would interfere with the fit of the splice bars.

Rails made from heats the test pieces from which have failed to stand the drop test or the bending test; rails having small flaws in the head and base, usually not to exceed $\frac{1}{4}$ in. in depth, if in the head, and $\frac{1}{2}$ in. in depth, if in the base; and rails possessing any other injurious physical defects, which, however, do not impair their strength, are designated second quality and are distinguished by having their ends painted. Specifications usually provide for the acceptance of a small percentage of second-quality rails, 3 to 5 per cent of the order being a common figure.

Rail Wear.—The conditions attending the wear of rails have not been thoroughly investigated, and so a good deal that is pretended to be known about it has come by theorizing. It is generally assumed that the natural wear between car wheels and rails is due largely to rolling friction, which is supposed to be the interlocking of the surface particles of the two bodies in contact, much as the teeth of cog wheels fit together. The friction between these meshing particles and the crushing of particles which fail to mesh are supposed to set up a sort of pulverizing action which gradually wears away the rail and wheel surfaces. The powder formed thereby may be seen by drawing the tip of the finger across the top of a rail just after a train has passed. Such is the commonly accepted explanation for rail wear on straight and level track. As for curved track, we know that other conditions obtain, for there is a grinding of the wheel flanges against the side of the rail head and there is a skidding action of the wheels across the rail top. The rapid rate of wear of rails on curves, as compared with that of rails of like quality on straight line, under similar traffic conditions, is too well known and understood to require lengthy discussion. It will suffice to illustrate a few examples of such wear. In Fig. 14 are exhibited a number of diagrams of worn rails, sketched from rails actually removed from the track. The legends noted on each section explain the length of service and other essential matters pertaining to the manner in which the rails were handled With the exception of the 90-lb. rail, laid in May, 1896, all of the rails were of the American Society standard section. It is particularly interesting to notice the small amount of wear upon the top surface relatively to that on the side of the head.

On grades, also, increase of wear, over that which takes place on level track, is an important exception to the explanation based upon rolling friction, and the difference is generally understood to be due to the predominance of the tractive effect of locomotive wheels. On the rolling friction theory this increased wear from traction is undoubtedly explainable in some part by the reaction between the minute particles of wheel and rail which gear with one another, between which there must be a constant tendency to slipping, if indeed slipping does not actually take place to greater extent than may generally be supposed. As the tractive effect of the locomotive on level track differs from that on grades only in degree, it is reasonable to suppose that no inconsiderable part of rail wear on level track must be due to locomotive traction. While the wearing effect of the car wheels may be essentially different from that of the locomotive drivers, we have to consider some tendency to slipping in the former due to inequality of circumferences, so far as such may exist between pairs of wheels on the same axle.

The actual behavior of rails under loaded wheels, particularly with reference to the conditions obtaining at the surfaces of contact, has been the subject of some investigation and experiment, and the data obtained certainly have some bearing on this subject of rail wear, even if opportunity to connect the same with formulated statements or rules of practice has as yet failed to materialize. Mr. Octave Chanute, when chief engineer of the Erie R. R., many years ago, made some experiments to determine the

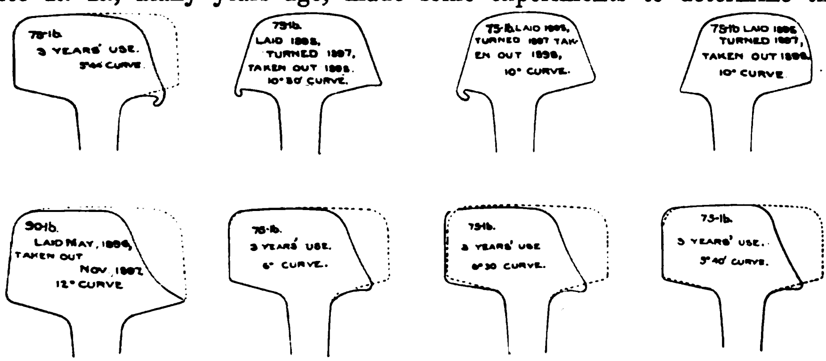


Fig. 14.—Examples of Rail Wear on Curves.

bearing area of locomotive driving wheels on steel rails, and subsequently Mr. D. J. Whittemore, chief engineer of the Chicago, Milwaukee & St. Paul Ry., and the late Prof. J. B. Johnson, at the time connected with the Washington University, at St. Louis, have conducted experiments with a like object in view. By jacking up a locomotive and placing sheets of carbon paper and tissue paper together under the wheels Mr. Chanute found that the area of contact of the wheel was about ¼ sq. in., as shown by the imprint of the carbon sheet upon the tissue paper. The driving wheels of the locomotives used in these experiments were 4½ ft. and 5 ft. in diameter, and were loaded with 11,350 to 14,000 lbs. per wheel. Mr. Whittemore, experimenting on a locomotive with 70-in. drivers carrying 16,000 lbs. each found, as the mean result of several experiments, an oval-shaped contact area having a major axis of 1.48 ins., across, the rail, and a minor axis of 1 in. longitudinally with the rail. In this case the tires were well worn and the (steel) rail had been in service five years. Another test with an engine having 64-in. drivers with loads of 13,800 lbs. per wheel, the tires having been in service about six months, gave a contact of similar shape, the major axis being 1.27 ins., the minor axis .79 in. and the area enclosed about .86 sq. in. Prof. Johnson experimented with locomotive drivers and car wheels, with loads imposed by a testing machine. On a steel rail with a top radius of 13½ ins. a 44-in. driving wheel with flat tread, loaded to 25,000 lbs., gave a contact which was approximately circular and 1¼ ins. in diameter. A new 33-in. chilled car wheel loaded to 15,000 lbs. gave an oval contact with a major axis of $1^1/_{16}$ ins., across the rail, and a minor axis of $^{13}/_{16}$ in. In another experiment a 44-in. driver with flat tread, loaded to 25,000 lbs., on a 75-lb. steel rail with a top radius of 14 ins., gave a contact approximating to a circle of $1^9/_{16}$ ins. diam. A car wheel loaded with 15,000 lbs. gave an oval contact measuring $1^3/_{16} \times \frac{3}{4}$ in.

So far as the actual area of contact is concerned the results of these experiments can be considered only approximations to conditions which may obtain in actual practice, for, in the first place, the loads were statically applied, and in the second place, the shape and size of contact would necessarily depend very much upon the condition of wheel tread and rail top with respect to wear. Neither did these experiments discover any relation between the chemical composition of the rail (hardness) and the effect of wheel pressure. By applying successively varying loads, however, Prof. Johnson deduced some laws which seem to shed a good deal of light upon wheel contact with rails. It was determined that the area of contact increases directly with the load, which shows that the mean intensity of pressure, in these experiments found to be about 82,000 lbs. per sq. in., is a constant for all loads. It was also found that the maximum deformation, which took place at the centers of the areas, in each case, was twice the average deformation, from which it follows that the maximum compressive stress for all loads is about 164,000 lbs. per sq. in. Permanent set of measurable magnitude, on either wheels or rail, was apparently not produced by these loads, from which it might be said that the elastic limits of the materials had apparently not been reached for this condition of contact, although for ordinary conditions the elastic limit of the rail steel was about 50,000 lbs. per sq. in. The principle that mean intensity of pressure and maximum intensity of pressure remain the same for all loads would seem to have an important bearing upon rail wear, as then the problem reduces itself to the relation of wearing effect to area of contact.

Whether the relations above stated might not undergo some modification for conditions which obtain more generally in practice might be worthy of inquiry. If, as is claimed, wheels and rails wear to the same curve (contour of cross section) we should expect that wheel contact under normal conditions would extend nearly or quite entirely across the top of the rail, approximating closely the form of a parallelogram with rounded corners. In that case it would seem that the maximum compression would occur along a line extending across the top of the rail instead of at a point or comparatively small area at the center of a circular or elliptical contact surface. On general principles, however, it would seem that the maximum intensity of compression could exert but little influence on rail wear, in any case, as if the rail should wear more rapidly on the line where the compression is greatest, the displacement of the material there would necessarily reduce the compression along that particular line of contact, thus affecting a redistribution or equalization of the pressure.

The allowable extent to which rails may be worn in depth of head before they are supposed to become unfit for main-track service seems to vary between $\frac{1}{4}$ and $\frac{1}{2}$in. quite generally, being $\frac{3}{8}$ in. in most cases, perhaps. It is true that a wear of $\frac{5}{8}$ or $\frac{3}{4}$ in. in depth of head, or even a greater depth, is occasionally reported of rails in main track, but such cases are so comparatively few that they may properly be regarded as exceptional. The condition usually considered to be the cause for the removal of rails from main track is very seldom charged to insufficient strength due to loss or abrasion of metal. On sharp curves where the lateral wear is excessive such a condition may sometimes obtain. The usual cause for removal is the roughening of the running surface, due to slivering or uneven wear of the metal, by which it sometimes becomes wavy. Of course this state of wear will depend largely upon the constitution of the metal with respect to homogeneity, but sometimes there are other causes for the removal of rails from main track before the limit of wear on the running surface has been reached; among which may be named deformation of the rail and abnormal wear of the running surface at joints, particularly at the receiving end of rails in double track; wear at the bearing surfaces of splice bars, and side wear on the outer rail of curves. The care exercised in keeping rails to smooth surface, particularly at the joints, is an important factor of their durability. Thus, for one or another of these causes, it will usually be found that rails of whatsoever weight will wear down about the same amount in depth of head, when they become unserviceable for further use in the main track. It would appear that, with the same quality of metal in either case, the larger rail, which would usually have the wider head, should wear the longer, but, as already explained, some rails of the larger sections have been disappointing in this respect.

It has long been a desire with maintenance-of-way officials to find some relation between the tonnage carried by rails and the endurance of the metal. It would be particularly useful if the wearing capacity of rails in relation to their chemical composition and known physical properties could be ascertained, for the quality of the metal is all important in rail wear. Such a diversity of results is obtained in practice, under apparently the same traffic conditions, that any attempt to draw conclusions as to the wear of rails from traffic, based either upon tonnage or the number of trains, without taking into account the quality of the metal, is futile. Occasionally some student of the question will formulate a rate of wear intended for general application, without reference to specific conditions, but the figures obtained do not usually agree with any widely prevailing experience. Taking into consideration the actual conditions there is but little about such a conclusion which seems strange. As hardness and compactness of the metal in the rail head, grades, curvature, the braking action of wheels, the number of trains, tonnage, and undoubtedly the wheel loads, all have some influence on rail wear, it could hardly be expected that a rate of wear based only on tonnage, number of trains or any other conveniently designated condition, would meet with general application. Nevertheless the wear of rails is usually referred to without any details as to the chemical composition and physical properties of the metal, wheel loads, speeds, curves, grades etc., when it is a question worthy of investigation whether with light rolling stock at moderate speeds a rail might not carry a much larger tonnage than with heavy rolling stock at high speeds, or whether the wear of soft rails under light loads might not be equivalent in some respect to the wear of harder rails under heavier loads. At least one consideration which would give weight to such comparisons would be the increased severity of the heavier loads on the joints. In Europe, where the population is more dense and the distances between stations shorter than in this country, a good deal of stress is placed upon the wear of rails under the braking action of wheels. On some of the French roads the rate of wear of rails at points where all trains stop is shown to be five times what it is at points intermediate between stations.

However these things may be, figures have been produced which serve to convey some idea of the duration of rails, within limits, even if one is not sure of being able to make a desired application of such figures; and then it is always possible to strike an average of any set of results howsoever various. The life of rails is variously estimated at from 100 to 250 million tons of traffic, depending upon the location of the rail with reference to straight line, curves, and grades. Some experiments conducted by the German Railroad Bureau during the years from 1878 to 1884 serve to show relative rail wear under different conditions of grades and curvature. The wear of the rails in depth of head per million tons of traffic passing over the rails was as follows:

Conditions.	Wear.
Level track on tangent	.0016 inch.
Level track on 2½-deg. curves	.0028 "
Level track on 5-deg. curves	.0039 "
Single-track tangent, grades ½ to ¾ per cent	.0067 "
Double track, 1¾-deg. curve, up grade ½ to ¾ per cent	.0032 "
Double track, 1¾-deg. curve, down grade ½ to ¾ per cent	.0043 "
Curves 2 deg. 50 min. to 1¾ deg. on ¾ to 1 per cent grades	.0087 "
Curves 2 deg. 50 min. to 1¾ deg., grades 2 to 2½ per cent	.0122 "
Curves 6 to 9 deg., grades 1½ to 2 per cent	.0087 "
Curves 6 to 9 deg., grades 2 to 2½ per cent	.0201 "
Curves more than 9 deg., grades 2 to 2½ per cent	.0378 "

On the basis of ⅜ in. wear the rails in level track on tangent, above referred to, should carry about 234 million tons of traffic, while under the most rapid rate of wear, namely that for rails on grades of 2 to 2½ per cent in curves exceeding 9 deg., the rails would carry only about 10 million tons. An interesting comparison is between rails on the up and down grades (as the trains run) of ½ to ¾ per cent, the wear being greater for the down grades than for the up grades, which seems difficult of explanation, even when the effect of braking the wheels on the down grade is taken into account. It is not stated in what manner the effect of side wear on the curves was taken into account.

The St. Gothard Ry., in Switzerland, has collected a very large amount of data with a view to determine the normal wear of rails under different conditions of grades and curvature. The following is a condensed summary of 87,000 measurements on the vertical wear of rails, the rate (average) in each case referring to a million tons gross carried: For the whole system (including grades) the rate of wear on straight line was .00134 inch.; for the whole system including curves, the rate was .00224 in.; for track on level grades the rate was .00209 in.; for track on mountain lines, down grade, 2.7 per cent, the rate was .00201 in.; for track on up grades, same lines, .00284 in.; for track on 2.6 per cent grades, traffic both ways, the rate was .00213 in. The sharpest curvature on these mountain lines is 6¼ deg. On this road it is found that the rate of wear on down-grade lines does not exceed that for level track. In respect to wear on curves the following coefficients were obtained, taking the rate of wear on straight line as unity: for curves below 2½ deg., coef. 1.3; for curves 2½ to 4½ deg., coef. 2.2; for curves of 4½ to 6¼ deg., coef. 3.1. It was also found that on curves the sectional wear on the inner rail was practically equal to that on the outer rail, for although the inner rail showed no lateral wear the vertical wear was more rapid than on the outer rail. This experience coincides with that on some of the lines in this country which carry a heavy freight traffic.

Mr. Richard Price Williams, an English authority, gives, as the result of numerous tests and observations, the average wear of rails of good quality to be about $^1/_{16}$ in. in depth of head for each 20 million tons of traffic carried. Allowing ⅜ in. as the limit for wear this would put the wearing capacity of an average steel rail at 120 million tons. The French engineer Couard puts rail wear at 1 millimeter for each 16,800,000 tons of traffic, and states that the limit of wear coming under his observation is about ⅜ in. This amount of wear would correspond to a carrying capacity of about 160 million tons. The wear of 100-lb rails outside the Fourth Avenue tunnel on the New York Central & Hudson River R. R., in New York City, is stated to be $\frac{1}{8}$ in. for 80 million tons of traffic, the average driving wheel load of all the locomotives passing over the rails being 22,000 lbs. About the best results noticed in this country are reported of 80-lb. rails on tangents, in use nine years, on the Michigan Central R. R., where the wear has been $^5/_{64}$ in. in depth of head, the rails carrying an estimated traffic of 90 million tons. If the service of these rails should hold out to the full extent of $\frac{3}{8}$ in. wear at the same rate the traffic carried would amount to 432 million tons. Some authorities think that the number of trains is a more logical basis for measuring the service of rails than tonnage. Passenger trains, while lighter, on the average, than freight trains, run at faster speed, and should be expected to wear the rails at a faster rate, ton for ton, than slow trains. So far as relates to parts of the rails at and near the joints there can hardly be any doubt about this. Tonnage multiplied by average speed is perhaps the proper basis for measurement of rail service, but as this product is practically the same for all trains, it is considered just as accurate to compare the wear with the number of trains. On mountain grades the tonnage of freight trains ascending is, of course, relatively small and the speed slow, but the wear from locomotive traction is relatively much larger than that from the car wheels, especially where the grades are so steep as to require pusher engines, and the frequent use of sand is also severe.

Some careful students of rail wear claim that it is an open question whether hard rails (speaking relatively) give longer service than rails of mild steel. The results of an experiment in this line carried out on the Dutch State Railways are quite interesting. Rails of hard and mild steel of known chemical and physical properties were laid in experimental sections under identical conditions of tonnage, speed, tie supports, ballast, alignment, etc. After 30,000 trains had passed over the rails they were taken up and weighed, and it was found that those made of mild steel showed 28$\frac{1}{2}$ per cent more wear than the hard rails. The rails were then put back and after 65,000 more trains had passed over the trial sections the rails were again weighed, when it was found that the hard rails had lost 9$\frac{1}{2}$ per cent more weight than the softer ones. The loss of weight under the whole 95,000 trains was approximately the same for both kinds of rails. Another interesting fact (which is similar to results observed elsewhere) was that the rate of wear per 10,000 trains was greater with the first 30,000 trains than with the next 65,000 trains, in the case of both kinds of rails. The rate of wear on single and double-track lines, other conditions being equal, was approximately the same. An extended study of rail wear completed about 1886 by Mr. Chas. B. Dudley, of the Pennsylvania R. R., showed conclusively that the rate of wear on rails of mild steel was slower than on rails of hard steel. Mr. Dudley has explained that the cold rolling effect of car and locomotive wheels on rails tends to increase the brittleness of the hard steel, and that the wear on brittle steel under rolling friction is more rapid than on mild steel. These results he has confirmed by experiments independent of those observed in the track.

Another phase of the rail-wear question which has received some attention is the effect of the traffic on the strength of the metal. Opinions regarding the "fatigue" of metal subjected to live loads or repeated stresses vary, and the theory is not generally accepted, at least as applying to rails. Test specimens cut from rails which have been in service long enough to wear the rail out have failed to show loss of strength in the metal, as compared with new metal of like chemical composition and manufacture. As to rails, the metal has comparatively long periods of rest during which "recovery" may take place after stress, and the "fatigue" theory is not put forth as prominently as is the effect of the face hardening of the running surface due to cold rolling from the wheels. It is claimed that from this cause the contact surface is broken down to a depth which varies according to the degree of hardness of the metal. According to some accounts it has been ascertained that a thin skin of metal on the rail top has, from the cold rolling of the wheels, been found to be twice as hard on the scale of hardness as the metal throughout the remaining portions of the rail. It is also claimed that the wearing qualities of rails of mild steel are affected to a greater degree from cold rolling than are hard rails. As already stated, it has been observed that rails wear most rapidly early in their life, which is explained by the gradual hardening of the top surface due to cold rolling by the traffic. One matter which should not escape consideration in this connection, however, is that an abnormal rate of wear should be expected of new rails until the top of the head becomes worn to fit the treads of the wheels. Especially is this the case where rails have been renewed with those of a new section having a considerably wider head. The grooves worn in the locomotive tires on the old rails are then liable to wear or crush down rapidly the metal on the corners of the head of the new rail. Prolonged seasons of freezing weather, when the rail is held rigidly to its duty in frozen ground, and frequent snow storms, which make traction difficult, also increase the rate of wear on rails.

Mr. W. G. Kirkaldy, in a paper before the Institution of Civil Engineers, in 1899, presented data obtained from a series of observations, to show that minute flaws or cracks are induced in the running surface of rails by the rolling action of the wheels, which impair the strength of the rail under certain test conditions. He fortified his claims by performing bending tests on butts of service-worn 75-lb. bull-head rails, in the normal direction and inverted, showing that the strength of the rail in the inverted tests was much less than when placed with the head upwards, as in service. As the head portion of bull-head rails is larger than the base portion the reverse would naturally be expected. In all the tests the loads were applied gradually, in increments of 2000 lbs., midway between supports 5 ft. apart. In six sets of experiments the butts tested in the normal direction were deflected 6 to 9 ins. (average 6.77 ins.) under loads varying from 48,355 lbs. to 63,670 lbs. (average 56,435 lbs.) without breaking, except in one case, where the rail snapped at a deflection of 5.62 ins., under a load of 57,705 lbs. In the inverted tests the rails snapped in every case at deflections of .28 in. to 1.31 ins. (average .86 in.), under loads varying from 33,980 lbs. to 40,080 lbs. (average 38,485). The rails had been in service 20 years and the metal on the running surface showed deterioration to some extent, although no visible flaws appeared except in one case. By tensile tests on specimens taken from the interior of the head and base portions it was proved that the deterioration was confined entirely to the top or running surface of the rail, and that "fatigue" of the metal throughout the section had not been produced. Substantially similar results have been shown by tests at the Watertown arsenal, in this country. Rails taken from the track and loaded in a testing machine, broke under relatively low stresses when the head was on the convex side of the piece tested, but by planing a thin skin of metal (about $^1/_{16}$ in.) off the top of the head the rails were able to resist the tests much more successfully. Microscopical examination in the Kirkaldy tests showed that the deterioration consisted of minute shallow cracks running across the top of the rail. It is a feature of carbon steel that a crack or flaw, however small, in the outer fibers of the piece greatly impairs its strength when subjected to bending stress which brings the defective fibers in tension. Impairment of strength in the manner shown by these experiments would not, however, apply to rails in service, because the tensional stresses imposed upon the top fibers by the undulations of the rail are small relatively to the tension in the bottom fibers. Neither would it be expected that impairment in any respect should become more pronounced with age. As the cold-rolling effect extends only "skin deep" and wears away as fast as it penetrates the head, it should be no deeper after a long service than at only a comparatively short period of the rail's life. So far as special tests and experience have proven anything, rails of good chemical composition produced by proper methods of rolling are—save for loss of strength by reduction of the section—no more liable to break in service when worn out than when they were new.

A simple way to compare the wear of rails of different composition and manufacture is to lay them alternately on sharp curves where the traffic

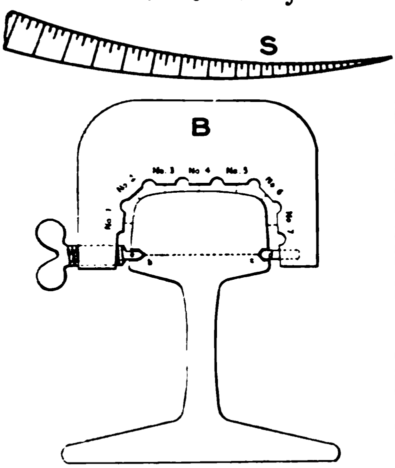


Fig. 15.—Instrument for Measuring Rail Wear.

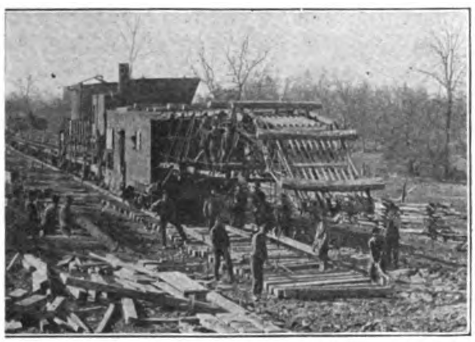


Fig. 16.—Hurley Track-Laying Machine; Front View.

is heavy. The rails will then be subject to uniform conditions of service, and any considerable differences of wearing qualities will soon become evident. By repeating this experiment on the same curve each year and keeping a rough check upon the volume of the traffic, the data collected should be useful for comparison of results from rails received from year to year, and might be valuable in deciding upon the kind of metal to be finally adopted. One way to determine the amount of wear on rails is to take the rails up and weigh them, but in experiments on an extended scale this method requires a good deal of labor; it also makes necessary a small correction for metal lost from the flange and web by corrosion, which can only be estimated. For obvious reasons ordinary calipers are not suitable for measuring rails to ascertain both lateral and vertical wear, or even the vertical wear over the whole width of the head. Various instruments and devices have been contrived for this purpose. One idea that has been put into service is to apply molds to the sides of the rail and take a plaster of Paris cast, from which precise measurements can be obtained in various ways. The instrument shown in Fig. 15, consisting of a clamp (B) and a curved-tapering scale (S), was designed by Mr. Stephen W. Baldwin, of New York City. The clamp is $\frac{3}{8}$ in. thick and is applied to the head of the rail by means of a thum-screw (e) and stud (d) in $^3/_{16}$ in. holes drilled into the rail at points where it is desired to take measurements. As the splice bars do not interfere these holes may be drilled as near the end of the rail as is desired. Presumably each rail would be measured at the middle and near the ends. The center line *b c* between opposite holes is the base line for all measurements, and as this is fixed and not affected by wear (the hole in the gage side should be drilled deep enough to place its pointed end beyond the reach of wear from the wheel flanges) the clamp, when adjusted, will always occupy the same position. To prevent corrosion in the holes they may be filled with wax after each time the instrument is used. The measurements taken between the working faces of the rail and the reference heads on the clamp (No. 1, No. 2....No. 7) are thus accurate records for comparing the size of the rail head at different times. The purpose of curving the tapering scale is to prevent bridging depressions in the rail surface. This scale is tapered and graduated to measure the open space between the clamp and the rail within $^1/_{200}$ of an inch.

7. Splices.—No subject concerned with track appliances has been discussed more than that of joint splices. A student of the rail joint question who would set about to read all that has been written concerning it by men of learning and experience would become weary before getting half way through. In this day and generation it is hardly possible to say anything on the question that is original; the arguments have all been repeated hundreds of times. Nevertheless it is appropriate to a work of this character to set forth the situation, and in that connection some treatment of the principles involved in the case seems desirable. The evolution of joint fastenings has advanced through three stages: first, the chair, which maintained the ends of the rails in alignment and served as a bearing piece or plate upon the joint tie; second, the fish plate, which afforded the rail ends some support under the head, but greatly improved matters by stiffening the junction of the rails vertically; third, the angle bar, which, combining the features of the fish plate, effected a great improvement in both the vertical and horizontal stiffness of the junction. The angle bar has long been the universal joint fastening, and, speaking generally, of course, it still maintains that distinction. Amidst the confusion of claims presented by the numerous designs of joint splices intended as improvements on the angle bar, railway men have been judiciously conservative about adopting new devices. The reasons for this moderation are apparent to any maintenance-of-way man of experience. Although the plain angle bar is not entirely satisfactory as a joint fastening, it is nevertheless safe, simple, easily applied and adjusted, cheap in first cost, fairly efficient and withal not such a rattletrap affair as some theorists would have us suppose. There is no getting around the fact that it is serviceable. Notwithstanding this there is a general demand for an improvement in joint fastenings, for, relatively, rail joints are the weak points of the track structure—not necessarily weak in an absolute sense, but comparatively so when measured by the stiffness of the solid rail. This relative weakness is an important factor of maintenance expense, for it interrupts the uniformity of conditions of support, so closely concerned with the maintenance of smooth surface, and it contributes to abnormal wear at the rail ends. Such consequences have not been removed by increase in weight of rail. The speed of trains may still be measured by the sound of the wheels passing the joints.

In order to thoroughly investigate the joint-splice question it is necessary to begin with first principles. A structure or body of any kind which rests upon the earth (where it is not solid rock or its equivalent) and bears up weight will settle into the ground. As proof of this statement it is only necessary to observe the walls or ground sills of old buildings, the sills of lumber piles, old stone fence, or indeed any heavy object lying upon the ground for a considerable time. The factors of the rate of settlement are extent of bearing surface, pressure, time, and weather conditions; settlement taking place much more rapidly during wet weather than during dry weather. All these conditions being present with track, it should not be surprising that track will settle. Track is composed of rails, fastenings and ties. The ultimate support for the track is the earth; the immediate support is the ballast. The bearing of the track upon the ballast is through the ties. The functions of the rail are to constrain the wheels and to distribute the pressure from the same over the ties. As we cannot expect to entirely prevent the settlement of track the highest result we can hope to attain is to get it to settle uniformly; but such cannot take place unless the pressures from the ties upon the ballast are approximately uniform. The difficulty in this respect is found at the joints, where the rail is relatively weak and unable to distribute the wheel pressure over the average extent of tie supports. The abnormal depression of rail and ties at this point gives rise to shock or suddenly applied loading, which still further augments the inequality of the pressure upon the ballast. The ideal service to be desired of a joint splice is, then, to make the rail as stiff at the joint as at any intermediate portion, and to so maintain it.

A mathematical investigation of rail flexure and stresses under an assumed loading is beset with two principal difficulties: the supports for the rail yield with the pressure, and they present a considerable extent of bearing surface, so that for different positions of the wheels, we are not sure that supposed points of support remain at fixed distances. As these conditions render it impossible to determine upon length of span, and as we know of no uniform conditions of settlement for ties under pressure, the solution of the problem defies computation. As a matter of practice, however, the depression of the ties is the only fact which gives us trouble. The depression of the unbroken rail between ties is too small to be of any consequence. We can compute the strength and relative stiffness of rails, but we cannot compute the relative stiffness of ballast or roadbed. In considering the sustaining power of rails we cannot separate the track from the roadbed: the two must act together. The fact that the two combined do not yield to satisfactory analysis surveys the whole difficulty. In approaching the question of joint splicing and support the same proposition confronts us. In fact, if the ties were not yielding supports there would be no joint problem at all; it would then only be necessary to "support" the joint upon a tie and bolt on a splice of sufficient horizontal stiffness to hold the rails in alignment. This is all very simple, but the principles stated have been frequently overlooked. Most men who have gone into the subject mathematically have figured the strength of rails and splice bars on the basis of rigid supports.

Following general principles still further let us consider the case of rails subjected to load without joint splices. Such a condition virtually occurs, so far as the support for the joint is concerned, whenever a splice in the track becomes loose. If the ties afforded rigid support to the rail each one in succession would have to sustain the entire load as the wheel rolled along, because, with the load directly over a support, a flexible beam is incapable of distributing any portion of the load to adjacent supports without being deflected. With the wheel at the end of a rail projecting past the last tie, as at a suspended joint, the joint tie in that case would sustain a pressure greater than the weight of the load, because the load would have a leverage over the tie. With yielding supports, such as we find in track, the conditions are essentially different. In that case the wheel load at an intermediate portion of the rail is sustained by three to six ties, according to the position of the wheel and the strength of the rail, and a single tie, as ordinarily bedded, never sustains the entire wheel load. So, also, at the end of the rail, two or three ties on each side of the joint are depressed as the wheel rolls past that point, and the tie next the joint, or underneath it, does not sustain the entire pressure from the wheel at the end of the rail, as in the case with rigid supports. Instead of a leverage over the last tie the wheel now has a leverage over two or three ties. The tie nearest the joint sustains the largest share of the load, but just what proportion of it we have no means of telling. From mechanical principles, however, we know that this tie sustains more pressure than ever comes upon a single tie at an intermediate point of the rail.

An error that is commonly made in analyzing the joint problem is the assumption that the joint ties are rigid supports and the rail ends cantilevers of the typical sort. On strict reasoning there is no illustration of beams in flexure, to which formulated mechanical principles apply, which fits the case. One writer has compared the situation with that of a flexible beam supported over water, on floats. We cannot treat the rail exactly as a beam continuous over several supports, because the tie at about the point where the deflection changes from downward to upward is sustaining only a small portion of the load, at the most. It is a case falling somewhere between the one where the load is all borne by one support at a time and one where the load is evenly distributed over a number of supports. It is customary, in comparing the deflection of the rail at a suspended joint with the deflection of the unbroken rail at some intermediate point, to liken the relative conditions to those which obtain with a cantilever sticking out of a wall and a beam "fixed" at both ends and suspended between two walls, the length of the cantilever being equal to half the span of the beam. In a case of this kind the deflection of the cantilever end is eight times that of the middle of the beam, for the same loading, and the relative stiffness is in the inverse ratio. As already suggested, however, such assumptions as to mechanical action are not warranted by the actual conditions. The depression of the ties and ballast nullifies the assumptions as to length of span of the deflected rail, and the undulation of the rail is not accordant with "fixed" end supports. The fact that the deflection of the rail between the extreme points of flexure does not take place over a clear span renders comparisons with deflection under known conditions largely conjectural. Thus, it may be doubted whether at the end of the rail any close resemblance to cantilever action ever obtains, because the length of the deflected end of the rail is always longer than the distance to the nearest tie, and the total length of rail deflected does not hang freely or unsupported, as does the end of a cantilever from the face of a wall. The fallacy of the situation is perhaps more easily seen when attempting to apply the cantilever principle to a supported joint. If in that case the tie "supported" the joint there would clearly be no cantilever, but the fact that it does partially support the joint leaves us quite at sea as to what length we should assume for the cantilever end. Some calculators have "cut the knot" by assuming the extreme condition that the tie affords no support at all, thus entirely changing the nature of the problem, for in that case we get a suspended joint of abnormal span. As to the actual flexibility of rail joints without splices, compared with that of the solid rail, experiment has shown the deflection of the joint to vary from five to 12 times that of the solid rail for the same loading, but in these results it was, of course, impossible to determine what influence the relative stability of the ground in the two places may have had on the deflections measured in the rail.

When we come to consider the dynamic action of the load we find that the rail ends, the splice and the joint ties undergo much greater pressures than can come upon the rail or ties at an intermediate portion of the rail. There has been much discussion as to whether a rolling load, like a train, passes over a rail as a load gradually or suddenly applied; and many have even questioned whether high speed in such a rolling load may not increase the pressures to something even greater than take place with loads suddenly applied—whether, indeed, such pressures may not be considered blows of less or more severity. Considering intermediate portions of the rail, and laying aside all reference to the effect of counterbalance and the rocking motion of the load, we may reason that the deflection of the rail in advance of the load fulfills the condition of a load gradually applied. Certain it is that in advance of the portion of the rail which is under full deflection there is some portion of the rail under partial deflection. But with the rail end the case may be different; for with a splice too weak, or too short, or too loosely fitted to fully transmit to the rail ahead of it the flexure in the rail behind, as such flexure proceeds toward the joint, the load may come upon that joint as a suddenly applied one. If little or no deflection precedes the wheel across the joint the wheel may meet the end of the next rail with a blow. Hence the severity of the conditions at that part of the rail where the deflection for even statically applied loads is greatest, must be apparent. Such is one of the causes of excessive wear to the rail on the receiving side of joints on double track: on the leaving rail end the load is gradually or statically applied, while on the receiving rail end it is suddenly or dynamically applied, or it may strike as a heavy blow.

In considering the strength of the rail at the joint we have to take account of the combined strength of the rail ends and the splice bars, for both assist in holding up the joint. Such is the fact for the reason that the rail is continuous beyond the joint ties. If we had to consider simply a beam supported at the two ends the case would be different. The same principle applies in considering the strength of the rail at an intermediate portion, for its supporting power depends not alone upon its resistance to bending at a point directly underneath the wheel load, but also upon the resistance to deflection due to the continuity of the rail over adjacent ties. As already indicated, the usual method of computation is to assume the rail ends to be cantilevers extending half a tie space beyond rigid supports (suspended joint), and then consider the pair of splice bars as a beam either supported at the ends or "fixed" at the ends, and loaded at the middle. By computing the deflection in terms of two unknown quantities (the proportional parts of the load sustained by the rail ends and splice bars) a ratio of the stiffness of these two means of support is found; and then by solving for the unknown quantities the proportionate loads carried by the rail ends and the splice bars are ascertained. It is then customary to double these figures for indefinite repetitions with reversal of stress, and then double again for suddenly applied load or shock. On this line of reasoning some pretty heavy stresses are found for the splice bars. As, however, no account is taken of depression of supports and the actual manner of the deflection of the rail, the figures obtained are necessarily conjectural. As a matter of practice splice bars seem to stand service much better than can be accounted for on the diagnoses of some of the doctors. A satisfactory analysis of the part which a splice must play in the support of a joint under actual conditions, with a view of arriving at even an approximation to the stresses in the parts, is indeed a perplexing proposition.

In discussing the joint question it is conventional to first point out the deficiencies of the angle bar and then look for such improvements as will overcome the stated defects. The plain angle bar fails to meet the ideal requirements of a splice in two important respects: it is not strong enough, and wear on the top edge, in the immediate vicinity of the joint, frustrates the maintenance of a close union of the parts. Taking up these defects in detail, we know that angle bars of ordinary make are not strong enough because they bend and take a permanent set in service, and occasionally one will break. As an improvement angle bars might be made much thicker than they usually are. In general practice railway men have been too sparing of metal in angle-bar splices, the weight of both pieces per yard being, in a great many cases, only 70 to 85 per cent of the weight of the rail. On a comparatively few roads the angle-bar splices are as heavy as the rail. It is entirely practicable to increase the ordinary weight 50 per cent without adding much metal to the horizontal leg of the bar, where it does not count for vertical stiffness. Such an increase will produce a pair of bars heavier than the rail, length for length, but, owing to the shallower depth, it is not practicable to make them as strong as the rail in resistance to deflection. On a rough calculation the weight of a pair of plain angle bars as stiff as the rail for which they are designed would necessarily have to be about three times as heavy as the rail, length for length. It then appears that there is no danger of overdoing the matter of strength by increasing, within practicable limits, the thickness of angle-bar splices. Thus it is shown how the plain angle bar fails to meet ideal conditions, for, inasmuch as the rail is broken at the joint, it is necessary, in order to preserve uniform stiffness past the junction, that the splice should be as stiff as the solid rail. Still, taking matters as we find them, any increase in the thickness of the bar must be considered an improvement. A good way to test the efficiency of a joint splice is to couple two rails together, end to end, and then let them swing clear from supports at the extreme ends. Loading should then be applied near the middle of the long span, with the rail in both the service and reversed positions. If the rail sags to a true curve and the splice does not take permanent set before the rail does it is shown to have bending strength equal to that of the rail.

The thickness of the top edge of the bar should be limited only by the width of the fishing surface of the rail head, due allowance being made for room to tighten the splice after wear takes place. Splice bars for rails with broad heads can be made thick, and in order to make the thickness a maximum the vertical leg of the bar may extend outside the plane of the side of the rail head, the projecting corner being beveled off or chamfered to give clearance to the wheel flanges. The inner faces of the bars should be flat rather than concave or dished out, as in the usual form. While this feature of design adds metal which does not largely increase the vertical stiffness of the bar, and while the space so filled may work some inconvenience in fitting bolts, if the rails have widely pulled apart, yet it does add considerable weight to the bars, which gives to the splice the advantage of greater inertia and should lessen the tendency to vibration and wear in case the bolts become slightly loose. Splice bars are dished out along the middle line to save metal and to facilitate punching the bolt holes. A thickened bar does not, however, stand in the way of making an oblong bolt hole, for a hole can be drilled the size of the shorter diameter and then finished by punching. As a matter of fact oval holes in the splice bars are not necessary to prevent the bolt from turning. The bolt may be made with an L-shaped head which engages with the horizontal leg of the bar, or it may be made with a square head which is prevented from turning by a shallow groove in the bar on line with the bolt holes, which may then be drilled. Splice bars with circular holes, grooved for a bolt with a square head, are standard on the Boston & Albany and the Chicago, Burlington & Quincy roads. In the former case the inside splice bar for the 95-lb. rails of the road has a groove $\frac{1}{8}$ in. deep and the circular holes for the bolts are $\frac{7}{8}$ in. in diameter. The holes through the web of the rail to correspond are 1 in. in diameter. The standard splice bar for the 100-lb. rails of the New York Central & Hudson River R. R. is 36 ins. long and has six bolts spaced 5.6 ins. centers. The shank of the bolt is $\frac{7}{8}$ in. square and it is held from turning by a hole in the splice bar $^{15}/_{16}$ in. square with rounded corners or fillets of $\frac{1}{8}$ in. radius. The other bar of each splice has circular holes $\frac{7}{8}$ in. in diameter. The web of each bar is $^{9}/_{16}$ in. thick and the weight of a pair of bars is 80 lbs.

Besides the severe bending stresses imposed upon the joint splice it is subjected to heavy shear. In the case of the plain angle-bar splice the shearing forces are applied through the fishing surfaces of the rail at and very near the joint. The top and bottom bearing surfaces of the bar are unequally fitted for the wear from this shearing force. Some writer has pointed out the humor of the situation in the remark that the rail is "hung up by the ears," which is a good illustration of actual conditions. The bottom bearing surface or horizontal leg of the bar is well designed to stand heavy pressure, but the top bearing surface is comparatively narrow, and the intensity of the shearing force, being concentrated on a length of only 2 or 3 ins. adjacent to the joint opening, first compresses the top edge of the bar, after which it is worn down by repeated blows from the springing of the rail ends. A close examination of an old angle-bar splice in track will usually show something like this: the splice will be found to fit the rails tightly at the end bolts, but will be .01 to .03 in. loose at the ends of the rails, or at the joint. This wear is mutual, taking place on both the splice bar and the under side of the rail head, and usually leaving a ridge of metal on the top edge of the bar in the expansion opening, where the wearing action is absent. Let it also be understood that the fishing surfaces of rails and splice bars are imperfect and not always capable of a close fit. One may observe on newly laid rails, with new splices tightly bolted, that occasionally a rail end will show slight looseness, and play up and down as wheels pass the joint. This looseness, whether due to badly fitting bars, in the first place, or to wear, is a serious defect of the plain angle-bar splice, for it permits of some deflection of the joint before the splice is brought under stress, thus reducing the efficiency of the splice. It may be seen, therefore, that the efficiency of a splice is not altogether a question of strength. In order that the strength of the splice may fully serve its purpose there must be a tight fit, so as to hold the two rail ends relatively immovable.

The conditions which bear some relation to the wear of splice bars are extent of bearing surface, the nature of the fit and the hardness of the metal. The importance of thick bars, particularly on the top edge, to afford a wide bearing surface, has already been dwelt upon. As to the fit of the splice, a good deal depends upon the length of the bars. Explaining more in detail what is above intimated, the finish of rails and splice bars is rolled surfaces, more or less rough, uneven and coated with oxide. As soon as the fishing surfaces adjacent to the joint opening begin to wear, a hinging motion of the rail ends takes place as the rail is deflected under wheel pressure; and the shorter the splice the greater is the hinging action for a given amount of wear; that is, with the shorter splice the rail ends have more chance to play without bringing stress upon the splice. In consequence of this fact the shorter the splice the more rapid is the wear. In illustration of this principle there are many familiar examples. In jointing up a fishing rod, for instance, one pushes the sections well into the ferrules, for the reason that if any looseness exists in the joint a short gripe of the ferrule permits of too much movement of the section. Examination of an old angle bar will disclose that it has come in contact with the rail at only a few places; sometimes only one bright spot can be found where it has come into close contact with each rail, and usually such spot is only a small portion of the available surface intended for contact. It must be obvious, then, that the shorter the splice the greater is the movement allowable for the rail within its gripe. If the fishing surfaces of rail and angle bars were planed surfaces, it might be possible to make a tight union with a short splice, and maintain it in that condition to better satisfaction than is the case in practice, but as such refinement of splicing is impracticable we have to look to the long splice as the next best thing of the plain angle-bar type.

Angle bars are usually designed to have the horizontal leg come even with the bottom of the rail. This arrangement divides the bearing between the rail and the splice bars. With a view to throw all the bearing upon the rail base, the bars are sometimes designed to stand $\frac{1}{8}$ in. clear of the ties, but the difference in this respect is quite likely unimportant. The spikes hold better on angle bars which come down even with the base of the rail. If the horizontal leg of the bar stands off the tie face the bearing comes against the spikes some distance above the tie, and they do not resist the lateral pressure as well as when it comes even with the tie face.

Length of Splice.—In practice the length of angle-bar splices varies from 20 to 48 ins. A splice less than 26 ins. long may be considered short and one exceeding 32 ins. in length may be considered long. The usual spacing of the bolts in splices of short and medium length is 5 to 6 ins., uniform spacing being customary but not always the practice. A spacing as short as 4 ins. is quite frequently found and 9 ins. is about the longest spacing. Short splices take four bolts and long splices six, but splices as short as 26 or 28 ins. sometimes have six bolts. Personally, my preference is for a long splice—not shorter than 42 ins. For a bar of that length I would space the bolts the following distances apart in inches: 8—6—6—6—8. For rails as heavy as 90 lbs. per yard I think it would pay to make the splice even longer—say 48 ins., with the bolts spaced at distances of 10—7—6—7—10 inches. Long angle-bar splices have been in service for many years, and the results, as compared with the use of short or medium-length bars, have been satisfactory in some cases and the reverse in others. So far as I have been informed the long splices which have failed to give better satisfaction than shorter ones have not been made heavy enough, being so light that they would bend under the traffic and in time take permanent set and hold the rail ends out of surface. I have never heard the opinion advanced that long splices would wear more rapidly than shorter ones; on the contrary the evidence always seemed to point the other way. The objection that long splice bars hold the rail so tightly as not to allow proper expansion for change of temperature, can be met by the argument that long bars, in order to hold the rail as firmly, do not need to be bolted up so tightly as do short ones.

Quality of the Metal.—Referring to the hardness of splice bars, it is to be noted that formerly they were made of wrought iron, and this practice still obtains to some extent, old iron rails being utilized to provide the material. Owing to the greater hardness and the consequent slower wear of the top fishing surface, steel is preferable. Steel for splice bars is usually of low carbon—about 0.10 to 0.12 per cent, 0.15 per cent being the maximum most commonly specified and .08 per cent about the lowest used. The manganese ranges from 0.30 to 0.60 per cent, silicon is not specified, and the limits on phosphorus and sulphur are about the same as in rail steel. Various standard specifications call for metal having an ultimate strength of 48,000 to 65,000 lbs. per sq. in. (usually 55,000 to 64,000) with an elastic limit as high as half the ultimate strength. The tensile tests must show an elongation of not less than 25 per cent in 8 ins., and a test specimen cut from the head of the splice bar must bend 180 deg., or flat on itself, cold, without fracture on the outside of the bent portion. In some cases the specifications require the same bending test to be made on an unpunched splice bar, the angle being flattened out before the bar is bent.

A few roads have used much higher carbon in splice bars than is provided for in the usual specifications. The New York Central & Hudson River R. R. standard specifications for bars not exceeding $^9/_{16}$ in. in thickness call for 0.25 to 0.30 per cent of carbon, with manganese, phosphorus and sulphur about the same as in the rail steel of the road. For bars exceeding $^9/_{16}$ in. in thickness the carbon is kept down to limits of 0.10 to 0.12 per cent, with manganese, phosphorus and sulphur about the same as in the other case. Silicon is also determined and fully considered. The bars made of the higher carbon steel are limited as to thickness of web so that they can be punched, it being found that with this quality of metal the punches and dies will not stand any reasonable amount of work on bars of greater thickness. It is to facilitate the punching of bars exceeding $^9/_{16}$ in. in thickness that the steel of lower carbon is used. A limited number of these low-grade steel bars is carried in stock by this company to meet repairs on leased lines where various types are still in use, but the high-grade bars are far more satisfactory and are used wherever high-speed trains are run. The Michigan Central R. R. has experimented since 1897 with splice bars of high-carbon open-hearth steel, the carbon running 0.65 to 0.75 per cent and the phosphorus about .05 per cent. In the testing machine splice bars of this metal show much better recovery after deflection than low-carbon bars, and in the track, when laid with new rails, they seem to give considerably better service than bars made of iron or of low-carbon steel. When applied to worn rails, however, these splices did not seem to maintain the joints in much, if any, better surface than the low-carbon bars which had been removed from the same rail.

Finish.—Splice bars should be rolled to a smooth surface finish, so as to fit the rail accurately, fishing tightly between the head and flange; and due allowance should be made to adjust for wear. The inside faces of the splice should not quite reach the web of the rail, no matter how tightly the bolts are screwed up. In order to fit in this manner the inner corners of the bars (which must be of small radius, so as not to unduly reduce the top bearing surface) should not fit snugly up against the fillets where the web of the rail meets the head and flange. Particular attention should therefore be paid to the hight of the bars, as determined by the fishing angles, in relation to the proper distance from the vertical center line of the rail section. Splice bars may be inspected for fit by applying them to a section of the rail for which they are made.

Specifications usually call for accurate shearing as to length and require that the punching shall not bulge the fishing surfaces opposite the bolt holes; and that the holes must be free from burrs. Some specifications require that the entire four or six holes, as the case may be, must be punched at one operation. Another point of much importance is that angle bars should be straight. In punching the bolt holes through the bar and in shearing it off it is liable to be bent and so left, making it impossible to fit the rail closely, for the bolts cannot be depended upon to straighten the bars. The extra expense of cutting off the bars by sawing would no doubt be found justifiable by the absence of crooked ends and "fins." The name of the maker and the year of manufacture are usually rolled in raised letters on the vertical leg of the bar, in such position as not to come under the heads or nuts of the bolts. The designation of the particular rail section to which the splice applies is sometimes included.

Devices for Taking up Wear.—Returning to the matter of the wear of splice bars, it may be noted that in foreign countries various devices are being used or experimented with as a means of reducing the shearing movement of the rail ends due to this cause. On many of the roads of France, Germany and Austria-Hungary metal packing pieces or liners made of hoop iron, or sheet steel cut to the desired form, are inserted between the bearing surfaces of rail and splice bar, in the gaps between the worn parts, to take up the motion due to wear. Of 17 companies reporting to the International Railway Congress on the use of metal lining pieces three expressed no opinion as to their utility, three attributed only limited success to their use, while eleven companies declared without reservation that they had obtained good results by using them. On the Emperor Ferdinand's Northern Ry. metal lining pieces for worn splice bars have been regularly employed since 1892, and are officially reported to have proven an excellent means for strengthening worn joint fastenings. These lining pieces are of a thickness of 1, 1½ or 2 millimeters, according to the conditions of wear. On lines of heavy traffic, carrying 8 to 10 million tons yearly, they last two or three years and are then replaced.

On the Prussian State and Imperial railways, of Germany, experiments are being made with a form of splice with auxiliary fishing plates of short length, which admit of being tightened independently, to take up wear. The splice proper, as will be seen in Fig. 17, consists of two Z-bars, the lower legs of which depend below the rail flange, to give depth to the splice, being cut away at the corners sufficiently to permit the (metal) joint ties to be brought to proper spacing. The upper leg of the Z-bar fits snugly against the web of the rail, but is not quite wide enough to meet the under side of the rail head. The proper fitting of the splice into the fishing sur-

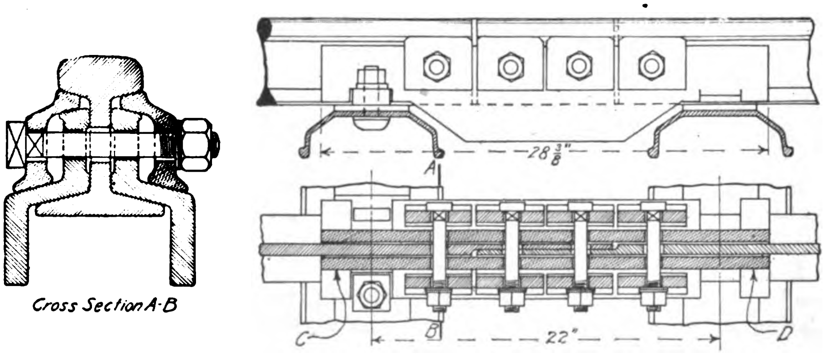


Fig. 17.—Splice with Auxiliary Fishing Plates, Prussian State Rys.

faces of the rail is then secured by means of four auxiliary wedge-shaped fishing plates, which fit into the space between the top edge of the Z-bar and the under side of the rail head, and upon the horizontal leg of the Z-bar. These auxiliary fishing plates are each about 4 ins. long. Being entirely independent of one another each may at all times be adjusted to maintain a close fit with the rail and to meet variable conditions of wear. As used on the roads named, there are, besides the form shown, two modifications of the same. There is one pattern in which a special bolt is used at each end of the Z-bar splice, being screwed up against the Z-bars direct, as at *C* and *D*, in the figure. In another pattern the general arrangement is as shown in the figure, except that when used with a lap joint one of the intermediate auxiliary fishing plates is omitted on each side. It is reported that this device has been giving good satisfaction.

Breakage of Splice Bars.—Splice bars break occasionally, and they usually, but not always, break by cracking from the top edge downward, either at the middle of the bar or through one of the bolt holes next the joint. The reason for this manner of failure is evident enough. The splice is subjected to bending stress in two directions, and as the top of the bar has no flange (none to speak of) it is very much weaker than the bottom and, of course, is the part where the heaviest strains occur. Running a few feet ahead of a rolling wheel there is an upward flexure of the rail which puts the top of a splice bar in tension. As the wheel draws near the joint the stress in the top of the bar changes to compression and so remains until the wheel is some distance past the joint, when it changes to tension again. Under a fast train, and particularly while the locomotive is passing, this reversal of stress takes place many times a second—about 12 times per second, at 60 miles per hour. As measured by Mr. P. H. Dudley (§ 181, Chap. XI.) the strains in the rail due to upward flexure seem to reach the maximum when there is a wheel on either side of the point under observation. This reversal of heavy stress is what cracks the bar, the metal undoubtedly being deteriorated most from the compressive stress, this being the heavier. If the top fibers become strained beyond their elastic limit it is only a question of time when they will part under the stress reversals. This is the reason why metal with a low elastic limit, such as iron and low-carbon steel, is considered by some to be less suitable for splice bars than metal of a higher grade.

A splice bar which has become worn in the middle or which has become bent down and taken a permanent set may not receive the full intensity of bending stress when the wheel is over the joint, owing to the extra burden imposed upon the rail ends. The heaviest duty which comes upon a permanently bent splice at a low joint occurs just after such a joint is raised to surface. When, in that case, the joint is lifted the tops of the splice bars are put in tension, and all the more so if the joint is raised a little higher than surface and the joint tie or ties tamped more strongly than the shoulder ties, to allow for settlement and to straighten the splice when the load comes on. Under traffic the tension on the top fibers of such a splice becomes excessive, and it is in this manner that large numbers of splice bars are cracked from the top downward. Such practice is approvable, because it is the only way to bring bent joints back into surface. The danger from cracked or broken splice bars is not as great in all cases as is sometimes supposed. Splice bars seldom break suddenly, but usually begin to fail by cracking, and the crack gradually deepens, so that opportunity is usually afforded to replace the defective bar before it fails completely. In view of the fact that splices in service are frequently found so loose as to afford no support to the rail ends, the breaking of a splice bar need not be regarded as a very serious matter, so far as joint support is concerned. If the broken bar is on the outer rail of a curve the danger of lip is the feature of greatest apprehension, but such cannot take place unless both bars break; and unless both bars break straight down, exactly opposite the joint opening, they may still be able to hold the rail ends in line. The point which I desire to make is that the breaking of a splice is not in all cases as serious a matter as the breaking of a rail.

Splice bars should not be notched for slot-spiking at or near the middle of the bar. Destructive consequences are bound to follow the notching of the outer fibers of a steel bar at a point where the greatest bending moment would bring the severed fibers in tension. A bar so notched is weakened to far greater extent than would be the case if the whole edge of the bar was planed off back as far as the notch extends into the bar. The best way to arrange for spiking splice bars to prevent or impede creeping of the rails is to make a bar with a wide horizontal leg, and then punch the spike holes through the leg instead of notching the edge. This arrangement makes both outside and inside spikes effective against spreading of the joint, and the splice bar cannot run away from the spikes, as it sometimes does when the latter are driven in notches the corners of which become rounded off by wear.

Effect of the Joint Opening.—Many students of the joint question seem to hold to the belief that the joint opening is the principal, or, at least, a very considerable, cause of low joints, by reason of the pounding effect due to the dropping of the wheels into the opening. The drivers of a locomotive are so large that they drop at the ordinary joint opening a distance which is not perceptible. A 33-in. wheel will drop into a joint opening of $\frac{1}{4}$ in. about .00048 inch. After a time it will be found that the edge at the rail end has been blunted back a little, so that the points where the wheel last touches the rail behind and first touches the rail ahead are about $\frac{5}{8}$ in. apart; into which space a 33-in. wheel will drop about .003 in., a fall hardly sufficient to give an appreciable blow. Indeed the tendency of the track to settle from the pounding of the wheels into such a small open space must be very small as compared with the tendency from the increased load which comes on the joint ties through decrease of stiffness in the rail at this point. That this is so is shown by the fact that there are places to be found in track where the joints have remained in surface several years; but if the blow delivered on every open joint was appreciable as a cause of settling track, the track at every such joint would either settle or else the blow would take effect upon the edge of the rail end and batter it. But the latter effect is not the case, for after several years' service good steel rails are not usually found battered as much as would result to the end edge by a single blow from an 18-lb. sledge hammer. At the joint opening there is usually some flow of metal, but with steel of desirable hardness this flowing does not become serious.

With the view of determining the effect of wheel pounding the experiment of cutting a narrow groove across the top of the rail with a hack saw, at an intermediate point, has been frequently tried. As a result the flow of metal under the rolling action of the wheels closes the groove and a slight depression is formed in the rail, but the pounding effect is not noticeable, so far as the surface of the track is concerned.

After a joint has settled some there is then a pounding which takes effect upon the track more and more as the joint settles farther down, for the sudden lifting of the wheel out of the depression greatly increases the pressure of the wheel upon the receiving rail. On double track this effect always takes place upon the same end of the rail, which accounts for the unequal wear of the two rail ends at the joint. Also, when a splice becomes loose, the rail ends shear by each other, up and down, as the wheel passes the joint, and the pounding effect upon the end of the receiving rail must be considerable, because the leaving rail end is depressed and the wheel meets the receiving rail end in the raised position, and must climb up on to it, as it were, thus delivering to it a blow which not only batters the metal but must also impart some momentum to the rail end in its deflection. The familiar clicking sound from the wheels passing the joints is due in some measure to the joint opening, but it is always louder when there is some play between rail and splice. As the wheel rolls by the joint, when it leaves the end of one rail and strikes the end of the other, it drives the rail head down upon the top of the two splice bars with a blow which gives out a cracking sound. This movement of the rail within the splice can best be seen when the rail is wet; that is, during or shortly after a rain, for then muddy water may be seen to squirt out of the loose places as the load comes on.

Miter Joints.—The supposed evil effects from an opening squarely across the rail at the joint has led to numerous schemes for carrying the wheel past the opening without dropping into it. One idea which has served this purpose is to so cut off the rail at the end that the joint opening does not extend squarely across the rail or else not entirely across it at one place. The miter joint (Engraving *T*, Fig. 20) is made by cutting the rail end off obliquely, or on a skew, usually so that the plane of the rail end makes an angle of 45 to 65 deg. with the vertical plane passing longitudinally through the web. Miter joints have been tried with varying success. They seem to have been experimented with most extensively on the Lehigh Valley R. R., where this form of joint, also known as the "Sayre" joint, was standard for many years, but was finally abandoned for the ordinary square-end joint. On some other roads the results from the use of the miter joint have been fairly satisfactory, and it is regarded as an improvement over the square-end joint. Such conditions as unsatisfactory quality of the metal and an unnecessary width of expansion opening may account for the shortcomings of the miter joint in some cases. An angle of 55 deg. is easier cut by the saw than one of 45 deg. and in some quarters is believed to give superior service, as the corners of the rail head are shorter and not so sharp.

It must not be understood that the miter joint entirely eliminates the dropping of wheels into the opening. As the rail top is curved, or eventually wears to that shape, only such wheels as fit the rail will pass over the joint opening without dropping into it. The contact between a new wheel and a rail with a curved top is so small that the wheel can find the edges of any joint opening at a practicable angle. In a certain contingency, as when a derailed wheel shears the splice bolts, the mitered end might form a dangerous joint, owing to the lip due to the lateral displacement of the rail ends, especially on the outside rail of curves; or during hot weather when the metal is expanding and there is a tendency for the rails to shove by each other. In anticipation of such trouble it has been proposed that the rail ends should be skewed as rights and lefts and the rails so laid on double track that the wheels will trail the points, in which case no danger from lip could exist.

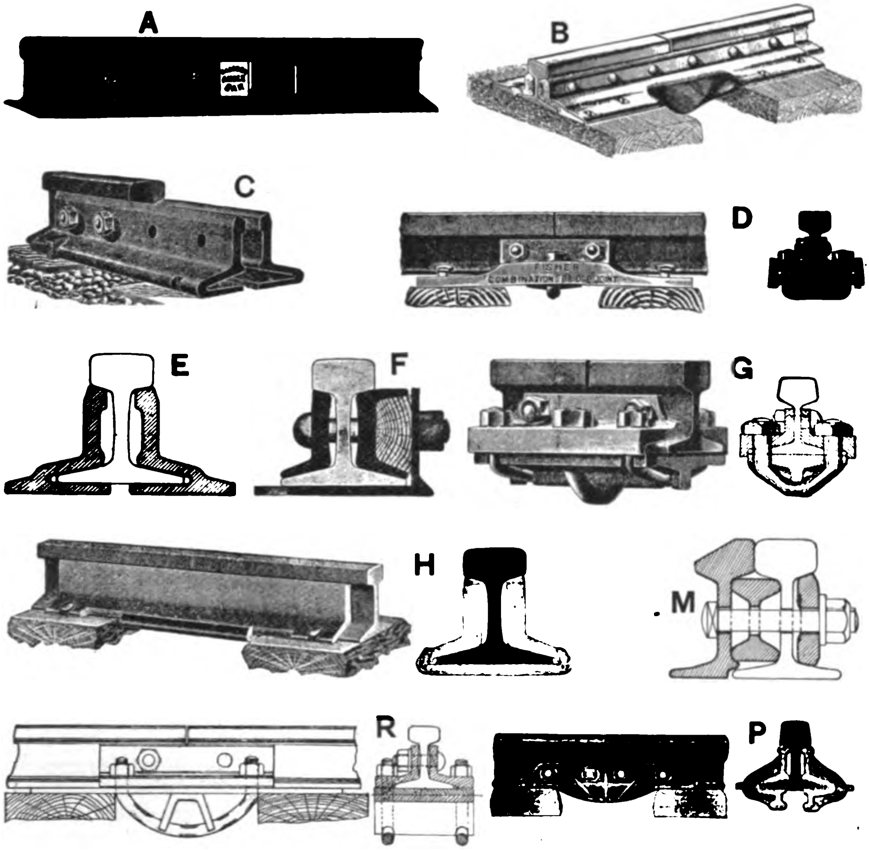
Lap Joints.—Another idea for carrying the wheel past the joint without permitting it to drop into the opening is found in the lap or scarf joint, which is made by halving or offsetting the rail ends on vertical planes to form an overlap, so that the joint opening does not extend entirely across the rail at one place. Some think that such a joint is better adapted to a rail with a curved top than a skew joint. As usually designed, the overlap is formed by halving the rail vertically through the web. While it would seem that the strength of the rail ends could be best preserved by a short scarf, say not to exceed 1 inch, as illustrated in Engraving *W*, Fig. 20, nevertheless where lap joints are being tried the long scarf seems to prevail, although the short scarf has been tried in a few cases.

Lap joints are not in service in this country, but on some European roads they are being tried to a considerable extent. Figure 17 shows a form of long lap joint that is being tried quite extensively, the lap in some cases being as long as $8\frac{3}{4}$ ins. This form of joint has been approved by the Prussian State railways, where it was being used on 124 miles of road in 1898, and it is also in service on the railways of Alsace-Lorraine and on the Austrian State railways. This joint enables the use of rails 49 ft. 3 ins. long on the Prussian State railways, without trouble from the increased opening necessary for expansion. The Haarmann-Vietor rail, named after two German engineers, who invented it, was designed with a view to form a lateral overlap or scarf at the joint without halving the web or weakening it in any manner. The rail is of unsymmetrical section, the web being non-axial, so that in forming a lap joint it is necessary to cut away only half of the head and base. The webs overlap at the joint and the rails are spliced with angle bars in the ordinary manner.

An eight years' trial of lap joints on the Kaiser Ferdinands Northern Ry. (1891 to 1899) proved a failure. A section of track about 3200 ft. long was laid with 86-lb. rails with joints lapping $9^3/_{16}$ ins. The thickness of the rail web was $^{11}/_{16}$ in. In a comparatively short time the lap ends became considerably battered and by the end of eight years, when all the rails were removed, 77 of them had broken at the lap. The splices were $21\frac{5}{8}$ ins. long and had four bolts.

Various Joint Splices.—It is hardly necessary to state that a great deal of experimenting has been done with joint-splice devices intended as improvements on the plain angle bar. Most of these splices have been patented and but very few of them have survived even a few years of trial. On general considerations some of the patented splices are clearly superior to the angle bar, because they embody all the principles of the angle bar, with additional features of apparent value, without multiplying parts. So numerous have been the trials of joint appliances, and so largely have experiments in this direction been disappointing, that sweeping statements favorable to this or that device are wisely regarded with some degree of misgiving. The joint-splice question has bothered railway engineers a great deal, and if there is any generality which is applicable to the matter it is perhaps best expressed in the following proposition: Practical men indulge in less and less talk about ideal splices, and more effort is being made in the direction of attempting some improvement or re-enforcement of the angle bar than in searching for some new-fangled appliance which might be expected to revolutionize things. It now seems to be quite widely conceded that some of the joint splices on the market, and others which are being tried by individual railroads, are giving better service than the plain angle bar. While a satisfactory test for a joint splice might be obtained in a few years, a period as long as the life of the rail must necessarily elapse before the ultimate worth of the device is demonstrated. Here follow illustrations and brief descriptions of some of the splices which have either received a long trial or are now being extensively tried, on the railroads of this country .

The ideas embodied in the so-called improved joint splices have for the most part taken three general directions: viz., in a stronger splice,



A, Sampson Angle Bar; B, Bonzano Splice; C, Continuous Splice (Old Pattern); D, Fisher "Bridge" Splice; E, Continuous Splice; F, Weber Splice; G. Fisher "Triple Fish" Splice; H, Permanent Splice; M, Barschall Splice; P, Price Splice; R, Long Splice.

Fig. 18.—Joint Splices.

either by thickening or deepening the section of the plain angle bar; in a firmer junction of splice and rail, usually by increasing the bearing surface of the splice, in one manner or another; and in attempts to overcome the drop of the wheel at the joint opening. The multitude of forms which inventions have taken includes many devices intended to combine two and sometimes all three of these features of improvement. One of the oldest ideas for increasing the bending strength of the splice was to thicken the angle bar in the middle. One form of splice embodying this idea is the Sampson bar, illustrated by Engraving *A*, Fig. 18, there being a protuberance of metal for the space of 4 or 5 ins. each side the joint opening, surmounted by another protuberance about 3 ins. long immediately covering the joint. Another direction in which this idea took form was in an angle bar of tapering section. Years ago such a splice was standard on the Chicago, Milwaukee & St. Paul Ry., the bars being rolled by eccentric rolls. For 67-lb. rails the splice was 40 ins. long, with 6 bolts, the thickness of the vertical leg being 0.597 in. at the ends and 0.875 in. at the middle. The experience which prompted this feature of design was the considerable number of breakages of angle bars on light rails under heavy traffic, it being clearly evident that the angle bar was, at least, lacking in strength at the middle. A great difficulty experienced in the rolling of these bars was to get them straight. The importance of having a splice of heavy cross section was early seen on the Lehigh Valley R. R., when rails not heavier than 52 lbs. per yard were used. With that weight of rail, it not being possible to have a heavy splice bar on the gage side, the outside angle bar was made about twice as heavy as the inside one, and the same depth as the rail, being grooved along the inside top corner, so as to fit against the side of the rail head.

The most usual, and in some cases the latest, scheme for strengthening joint splices is in the use of bars of deeper section, the typical arrangement being a deep bar depending below the rail base and between the ties of a suspended joint. About the simplest device of this kind is the Bonzano splice, which has been tried somewhat extensively on the Canadian Pacific, Pennsylvania, Philadelphia & Reading and other roads. This splice is shown as Engraving *B,* Fig. 18, being simply an angle bar with a horizontal leg of abnormal width bent down in the middle to deepen the section where the greatest bending stress comes. The bars are first rolled as ordinary angle plates, the intention of the wide flange being to give lateral stiffness and increased bearing surface on the ties. After being cut to length and punched for the bolt holes the bars are heated and the flange at the middle portion of the bar is bent down from the horizontal to a vertical position, to increase the depth and stiffness of the bar. The sectional area of the two splice bars is from 1.20 to 1.25 times that

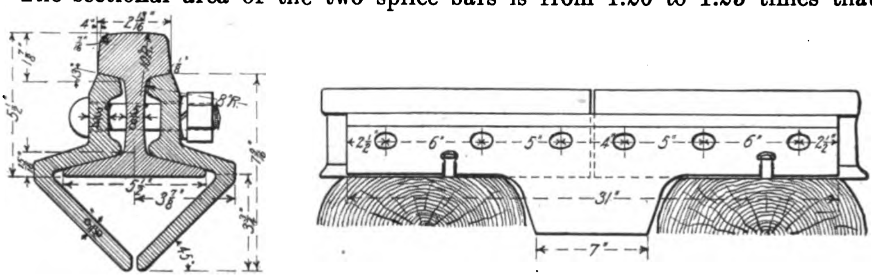


Fig. 19.—"M W 100 Per Cent" Splice and 100-lb. Rail, P. R. R.

of the rail to be spliced. Formerly this splice was made with a vertical camber of $\frac{1}{8}$ in., which, when the bars were bolted to the rails, gave the joint a camber of about $^1/_{16}$ in. It was expected that after a few trains had passed over the joint the scale of the metal would wear off at the center of the bars and the camber would be reduced to a straight surface. The advantage sought by the camber was to obtain a tight fit for the splice at the center, and although this feature seemed like an excellent idea, it had to be abandoned, for it was found that the camber put into the joint would not come out, even under the heaviest traffic and the heaviest wheel loads of locomotives. This splice is now made without camber.

Another splice of deep section, prominently known, is the "M W 100 Per Cent" splice of the Pennsylvania R. R., designed by the late M. W. Thompson, while principal assistant engineer. The name of the splice is intended to designate its relative bending strength, or stiffness, which is supposed to be equal to that of the rail on which it is used. The latest pattern of this splice, as designed for the standard 100-lb. rail of the road, is shown in Fig. 19. As is apparent, this splice is a development of the angle bar, having the very wide horizontal leg bent under at an angle of 45 degrees to the horizontal, so as to nearly meet the bottom leg of the other splice bar underneath the center of the rail. This splice is 31 ins. long, and all except a length of seven inches of the under portion of the bars is cut away, to clear for the joint ties. The total depth of the splice is $7^9/_{16}$ ins., of which a depth of $3\frac{5}{8}$ ins. depends below the rail base. The weight of both bars of the pair is 83.2 lbs., the moment of inertia is 53 for the pair and the sectional area of the pair at the middle is 13.94 sq. ins. The distance from the neutral axis to the lowermost fiber is 4.04 ins. The moment of inertia of the 100-lb. rail is 36.5, the sectional area 9.7 sq. ins., and the distance from the neutral axis to the lowermost fiber, 2.66 ins. The corresponding data for the ordinary angle-bar splice for the same rail, 34 ins. in length and weighing 75.4 lbs. per pair, is: moment of inertia for the pair, 8.06; sectional area of the pair 8.04 sq. ins.; distance from the neutral axis to the lowermost fiber, 1.71 ins. These data enable a comparison of the stiffness of the two types of splice. The bar shown is the development of four years of study and experiment, 60 miles of track laid with 85-lb. rails having been spliced with an older form of the bar, in which the extra metal in the horizontal legs of the splice, over the tie, was not cut away, but was extended out horizontally to form flanges bearing upon the ties. It is to be observed that the bottom flanges of this splice do not interfere with the action of tamping bars. The vertical axis of each bar of the splice is within the web portion that is gripped by the bolts, and as the vibrations of the lower flanges under stress are inward and upward, the tendency of the bars when the joint is loaded is to hug the rail. Another scheme for strengthening the joint splice in the middle was by means of a trussed support, usually including a bearing plate, with angle bars to hold the rail laterally. The Price and Long splices, Engravings *P* and *R*, respectively, Fig. 18, were of this form.

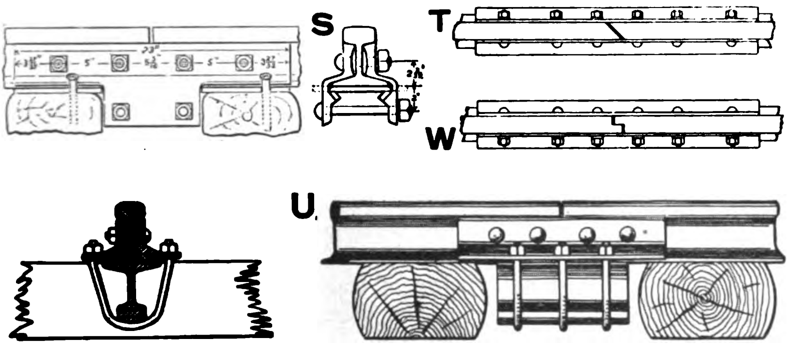
The idea of securing a firm junction of the splice and rail has usually led to the use of a base plate, primarily to support the rail ends at the base, thus affording bearing surface to relieve the top edge of the angle bars from wear, and incidentally to effect an equal distribution of the load upon the two joint ties, in the case of a suspended joint. The simplest device of this kind is a plain base plate used in addition to the ordinary angle bars. The standard joint splice of the Chicago & Northwestern Ry. is of this type, the base portion being a channel plate 24 ins. long, with $\frac{1}{4}$-in. flanges, the thickness of the plate under the rail being $\frac{1}{2}$ in. The rail ends (suspended joint) simply rest upon the plate and are not bolted thereto, but holes are punched through the plate for the spikes. One of the older forms of base-plate splices is the Fisher "Bridge" splice, which has been extensively tried. This splice, which is shown as Engraving *D*, Fig. 18, consists of a cambered channel or beam in combination with a pair of short angle bars bolted to the rails with two bolts through the web and with a U-bolt which holds the angle bars and rail firmly down upon the base plate. The corners of the rail are notched for the U-bolt and the angle bars are not permitted to reach the under side of the rail head, it being the intention to throw all the burden of supporting the rail ends upon the base plate. A later form of the Fisher device is known as the "Triple Fish" splice, shown as Engraving *G*, Fig. 18. This splice consists of a short base plate and pair of short two-bolt angle bars which "fish" only with the rail flange, the vertical leg of each bar not being quite deep enough to reach the under side of the rail head. There are three U-bolts holding the angle bars and base plate firmly to the rail flange, the idea in this splice, as in the case of the "Bridge" splice, being to support or stiffen the rail at the base and not at the head.

The simplest form of joint splice combining a base plate with an angle bar, and which also carries the distinction of having the fewest number of parts, is the "Continuous" splice, shown as in Engraving *C*, Fig. 18. This splice is in use on a large number of roads, and is so simple in construction that description is hardly necessary, any more than to say, perhaps, that it consists of a pair of angle bars with the horizontal legs widened out and doubled nearly half way under the rail base. Aside from the base-plate feature of this splice it will be noticed that it "fishes" with both the top and bottom faces of the rail flange. A later design of this splice, known as the "Extension Base" pattern, has tie-bearing flanges punched (not slotted) for the spikes (Engraving *E,* Fig 18). Another form of the base-plate type of joint appliance that has been extensively put into service is the Weber splice, shown as Engraving *F,* Fig. 18. It is composed of four parts besides the bolts, as follows: an ordinary angle bar and a channel bar fishing into the rail in the ordinary manner; a wood filler fitting into the channel bar, to act as a cushion against which the bolts are tightened; an angle plate, called the "shoe angle," the vertical leg of which bears against the wooden filler block and the horizontal leg of which serves as a base plate for the support of the rail ends.

The Heath splice, which was extensively tried on the Atchison, Topeka & Santa Fe Ry., was in one respect similar to the Continuous splice, in that it consisted of an angle bar with a wide horizontal leg doubled under the whole width of the rail base and extending some distance beyond the other side. In combination with this part there was a plain fish plate, the two being bolted together through the web of the rail in the ordinary manner. In one pattern of this splice the base portion was bulged downward under the joint opening, to afford extra stiffness. Strange though it may seem, a joint splice without bolts has been tried on main track under high-speed trains. This device is shown as Engraving *H,* Fig. 18, and is known as the "Permanent" splice. It consists of a pair of ordinary angle bars held to the rail by a base clamp or flanged base plate. The principle upon which the splice holds the rail ends firm is that, as the weight comes upon the joint the bars are made to gripe the rail all the tighter. At the center of the clamp there is a lug fitting into a notch cut out of the rail ends, to prevent the rail from creeping through the splice.

Of splices combining the two features of base support and bars of deep section there are at least two forms deserving of mention. The Churchill splice, used on the Norfolk & Western R. R., designed by C. S. Churchill, while engineer of maintenance of way of that road, consists of a pair of Z-bars fitting the rail as ordinary angle bars and depending about 3 ins. below the rail base for a length of 8 ins. between the joint ties. As shown in Engraving *S,* Fig. 20, there is a flanged base plate fishing with the lower legs of the Z-bars, which are held firmly to their work by means of two bolts. The "Crop-End" joint splice of the Michigan Central R. R., designed by the late Chief Engineer A. Torrey, consists of ordinary angle bars with an inverted piece of rail 11 ins. long, slightly cambered and placed base to base with the track rails, under the joint, as shown by Engraving *U,* Fig. 20. Two or three U-bolts are passed around the inverted piece and secured through holes in the horizontal legs of the angle bars, thus splicing the under piece of rail firmly to the ends of the track rails, the idea being to provide a strong splice by increasing the depth and also to prevent the rail ends from playing up and down and wearing the angle bars. This splice takes its name from the under piece of rail, which is obtained from the process of trimming rails with a rail-sawing machine, described in § 175, Chap. XI. In some cases in practice the middle U-bolt shown in the figure is omitted. An advantageous feature of this splice is that it can be applied to the rail while rail renewals are in progress without stopping to space the joint ties, which may be rearranged and the crop end applied at convenience. A somewhat serious objection against almost all other forms of deep-section splices is that the joint ties must be respaced while rail renewals are in progress, unless resort is had to the undesirable practice of making frequent cuts. The Crop-End splice was at one time the standard joint fastening of the Michigan Central R. R., and in 1900 was used on 390 miles of track. One feature of the device which was demonstrated was that it maintained a stiff joint—so stiff indeed that there was some question whether the rail ends did not suffer more where this splice was used than they did with a splice which permitted them to run away from the wheel. After a trial of six years the use of this splice was discontinued. The application of the crop end to joints on old rails generally improved the surface at the joint very much, particularly on rails where the traffic ran in one direction only. The serviceability of the crop end may be inferred from the use of some crop ends of 30-lb. rail under 60-lb. traffic rails, where it was found that the stress upon the joint splices bent the crop ends so that they sagged fully $\frac{1}{8}$ in.

There have been two ways of attempting to prevent wheels from dropping into the joint space, namely by cutting off the end of the rail in a manner to avoid an opening squarely across the same and by the use of wheel-bearing outer splice bars. The miter and lap joints have already been referred to. Splices designed to carry the wheels past the joint without jumping the opening were used as early as 50 years ago, and a number



S, Churchill Splice; T, Miter Joint; W, Scarf Joint; U, Torrey Crop End Splice.
Fig. 20.—Joint Splices.

of forms have been experimented with without permanent success. A late type of this splice consists of an angle bar or fish plate for the gage side of the rail and an "auxiliary" rail of suitable length, with the flange planed off one side to permit it to fit against the outside of the traffic rail in place of the outer splice bar. In the Barschall splice (Engraving *M*, Fig. 18) the fishing of the outer or "carrier" bar is obtained by means of a cast I-shaped filler placed between the carrier rail and the traffic rail, the bolts required being about 6 ins. long. The top of the carrier or "lifting" rail is on a level with the traffic rail and is beveled off at the ends to afford an easement in lifting the wheels. It bears direct upon the joint ties, usually on tie plates. A number of years ago some splices of this type were tried on the New York, Pennsylvania & Ohio (now Erie) R. R. with unsatisfactory results. It was found that the outer "flange" of guttered wheels would strike the piece of carrier rail heavily and that it formed an excellent anvil for guttered wheels to strike upon and pound down the joint ties. It was thought at the time by some of the people connected with this road that these trial splices might have been responsible for a noticeable increase in the number of wheels broken on the division where these splices were located. Such is the principal objection to this type of splice: a new wheel, by reason of the coning, will ride the traffic rail without touching the auxiliary, while a worn wheel will ride the auxiliary piece without touching the traffic or main rail. On the improved form of this splice, shown herewith, the larger portion of the head of the auxiliary or carrier rail is chamfered down to clear the "double flange" of guttered wheels. Of course this diminishes the bearing surface of the splice, but it removes, at least to some extent, the anvil-blow effect. It is intended particularly that this splice shall be suitable for use with long rails, one objection to the use of which is the wide joint opening necessary for expansion. On the Pennsylvania Lines West this splice is used on rails of 60-ft. length, and it is thought by the officials in charge that it has been the means of prolonging the life of rails under heavy traffic on double track, which had become badly worn on the drop side of the joint. These splices were manufactured in the company's own shops. As used on this road it is stated that no pounding from guttered wheels is noticeable. This form of splice originated in Germany, where it is known as the "Stossfangschiene."

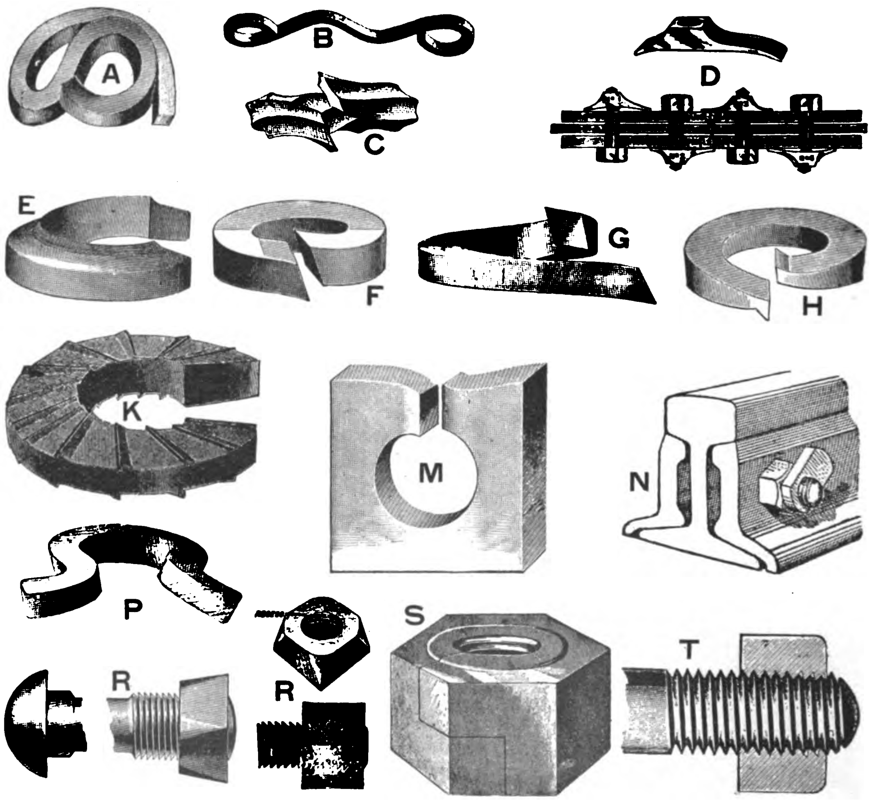
A good way to test the merits of different kinds of joint splices is to put them in adjacent sections of track on new rails of the same weight. The roadbed and ballast conditions, ties, etc., should also be similar, and careful account should be kept of the cost of surfacing required to hold the track in smooth condition. In order to eliminate possible local influences each of the trial sections should be at least several miles in length. About 1899 the Pennsylvania Lines West began a systematic study of the joint question which resulted in the selection of six of the patented splices on the market and laying them in 10-mile stretches for trial. They were applied to 60-ft., 85-lb. rails of American Society section. These experiments also included tests of angle bars of standard section rolled from axle steel and from nickel steel (3 per cent nickel). The systematic observations made on the behavior of these splices should yield instructive data.

8. Bolts.—The standard sizes of track bolts are $\frac{3}{4}$ in., $\frac{7}{8}$ in. and 1 in. in diameter, the most usual lengths being 4 and $4\frac{1}{2}$ ins., although the proper length depends, of course, upon the design of the splice bar and the kind of washer or nut lock used. A few roads use bolts $^{13}/_{16}$ inch in diameter, but it is an odd size. There seems to be no uniformity of practice regulating the size of the bolt to the weight of the rail. On numerous roads $\frac{3}{4}$-in. bolts are used on rails as heavy as 80 and 85 lbs. per yard, and in a few instances on rails even heavier. About the lightest rail on which $\frac{7}{8}$-in. bolts are used extensively is the 75-lb. section; for heavier rails, except where $\frac{3}{4}$-in.bolts are used, the $\frac{7}{8}$-in. bolt is the common standard. On a comparatively few roads 1-in. bolts are used for rails weighing from 80 to 100 lbs. per yard, but in the most general practice the $\frac{7}{8}$-in. bolt is standard for the heaviest rails, which includes, of course, 100-lb. rails. Neither does there seem to be any uniform practice regulating the size of the bolt with reference to the number used in the splice. In numerous instances $\frac{3}{4}$-in. bolts are used on rails as heavy as 85 lbs. per yard, in 4-bolt splices, and just as frequently $\frac{7}{8}$-in. bolts are used on 75 and 80-lb. rails, in 6-bolt splices. It would seem that some standard might be recognized whereby the bolt would be sized according to the weight of the rail, say $\frac{3}{4}$-in. bolts for rails weighing 65 lbs. per yard or lighter; $\frac{7}{8}$-in. bolts for rails weighing 70 to 85 lbs. per yard, inclusive; and 1-in. bolts for rails weighing 90 lbs. per yard and heavier. It would then seem that in case of any question the 4-bolt splice should be given the benefit of the larger bolt.

The most common form of track bolt has a button head and an oval neck, the latter to correspond to the shape of the hole in the splice bar, so designed to prevent the bolt from turning. Other arrangements for holding the bolt from turning are referred to under the subject of "Splices," § 7. Track bolts and nuts should be carefully made. It is poor economy to buy cheaply-made goods of this kind. The wearing face or rim of the bolt head should be at right angles to the neck, to obtain an even bearing on the splice bar, and to avoid excessive wear it should be wide enough to catch a good bearing around the bolt hole. The neck of the bolt and the bolt hole should, for the same reason, be designed for a close fit. For strength the thickness of the nut should be at least equal to the diameter of the bolt, and the nut should be tapped at right angles to the wearing face, which should be flat. The thread of the bolt should fit the female screw of the nut truly and, except for two or three turns at the end of the bolt, at starting on, it should fit it snugly. The threads should be cut in oil. Dipping the bolt in oil after cutting the thread in water will not prevent rust. Much time is wasted in putting on and taking off nuts where the bolt is too long. The length of the bolt should be such that it will not extend more than ¼ in. past the nut after it is screwed home. Any extra length performs no particular service. The most convenient shape for the nut is hexagonal: a nut of that form is more readily caught by a wrench and much more quickly turned on or off than is a square nut.

In the use of bolts of the ordinary pattern it is not good practice to screw the nut up against the splice bar without a washer of some kind. The consequence of such practice is that the rails in expanding or contracting will force the thread of the bolt against the side of the hole in the splice bar and batter or destroy it, thus making it impossible to tighten the nut any further. An ordinary metallic washer alone gives no better results. In former years compressed fiber and wood blocks were much used for washers, a metallic washer being placed between such material and the nut. Fiber washers of good material, when properly handled, gave good satisfaction. They preserved the thread of the bolt intact next the bearing face of the nut, and the cushion-like bearing rendered the bolt less liable to break when very tightly screwed up. One serious trouble with these washers was that if they became wet or damp before being put to use they would soften, and when in that condition were not able to stand the pressure of the nut. The same trouble arose with washers soaked by rain when the nuts became loose. The wooden washer in most extensive use was a strip of oak about ⅞ in. thick bored to fit over two bolts. They were made of scrap pieces in the car shops, at small cost, and were sometimes soaked in oil. The principal trouble with these wood washers was that they softened after a few years' exposure to the weather, and split. If the nuts were tightened during wet weather (the time usually selected by trackmen for such work) they would crush. To overcome the trouble of splitting the Kansas City, Fort Scott & Gulf R. R. used a splice devised by Mr. J. M. Buckley, consisting of an angle bar for the gage side and a channel bar for the outside of the rail, with a strip of wood fitting in the groove of the channel, as with the Weber splice now. The bearing of the nut was received by an iron washer overlying the wood, but the rails (56-lb.) and splices outlasted the wood and it was gradually replaced with cast washers to fill up the space in the groove so that the nuts could be tightened. Although the principle of cushioning the pressure of the bolts against the splice bars seems like a good idea, the use of wood and fiber for the purpose has largely passed out of practice.

Nut Locks.—Nut locks are contrivances intended to prevent nuts from turning off or loosening when subjected to vibration or jarring. They are of three kinds: positive, or those which positively hold the nut from turning; spring locks, which are supposed to act constantly upon the nut with spring pressure, thus taking up any looseness which might come from wear; the third arrangement is a grip nut or bolt or "lock nut," of which there are several kinds. A common type of positive lock consists of a washer of sheet metal with a projecting corner or edge which can be bent up against one of the sides or corners of the nut. The Jones nut lock is of this kind. Another common form of positive lock consists in the use of a key. The Cambria angle bar is rolled with a rib on the horizontal leg, close by the vertical leg, forming a groove directly under the nut. By driving a tapering key into this groove and bending up the end the nut is held from turning and the key cannot slip out. The grooved bolt is another familiar type of a positive nut lock. The Stark pattern has a key seat on the bolt and corresponding seats in the nut, so that the nut need be screwed but part of a turn after it is tight, in order to bring the two seats together for the insertion of the key, which is a spring U-pin. The Champion nut lock is of the same general type but has a ring or rib of metal on the outer face of the nut which is punched down into the groove in the bolt when the nut is screwed home. A very simple method of locking nuts, sometimes employed to keep the bolts tight on crossing frogs, is to file a groove across the wearing face of the nut, outside the aperture, and then with a cold chisel cut a groove in the face of the splice bar to correspond with that in the nut, and drive in a split key after the nut is



A and B, Excelsior Single and Double Nut Locks; C, American Nut Lock; D, Automatic Rail Joint Spring; E, National Lock Washer; F and G, Verona Nut Locks; H. Positive Nut Lock; K, Harvey Ribbed Washer; M, Eureka Nut Lock, N, Young Gravity Lock Nut; P, Standard Nut Lock; R, Harvey Grip Bolt; S, National Elastic Nut; T, Oliver Lock Nut.

Fig. 21.—Nut-Lock Devices.

screwed home. The position of the groove in the splice bar is found by first screwing home the grooved nut. As the splice becomes loosened from wear the keys may be temporarily withdrawn and the nuts tightened. On crossing frogs of the Michigan Central R. R. both the nuts and the heads of the bolts are held in this manner. Still another simple method of locking nuts positively is to burr up the metal of the splice bar behind a corner of the nut. To lock a track nut positively is a simple matter, but still inventors keep on studying.

Prevention of the nuts from turning does not by itself accomplish all that is desirable in nut locks for joint splices. The wearing down of the roughness and scale on the bearing surfaces of rail and splice bars, the elongation of the bolts and the wear from the bearing faces of bolt heads (especially badly fitting bolt heads), makes desirable some means for automatically maintaining the bolts in tight adjustment. A common type of elastic lock for this purpose is a spring washer, usually consisting of a coiled bar of one turn. A number of designs are shown in Fig. 21. Engraving *A* is the Excelsior single lock and Engraving *B* the Excelsior double lock. The double coil of the former prevents the device from being jammed into oblong bolt holes in splice bars, and its outline shape prevents it from turning with the nut. The double pattern is bent in the middle, to meet the splice bar convexly, and is coiled at the ends to fit over a pair of bolts. The National lock washer (Engraving *E*) fits the bolt closely, is made of hardened steel and has a rib around the edge of the aperture for the purpose of forcing some of the metal of the nut into the thread of the bolt, thereby locking the nut. The Verona nut lock (Engraving *F*) is a plain bar of square cross section spirally coiled. The improved Verona pattern (Engraving *G*) has a tail to engage with the lower leg of the angle bar and prevent the device from turning on the bolt. The Positive nut lock (Engraving *H*) is a variation of the old-style Verona, having barbs at the tips to cut into the nut and splice bar and lock the nut. The Standard nut lock (Engraving *P*) is a coïled and twisted bar with the ends turned out to keep it from getting into the elongated hole of the splice bar. The American nut lock (Engraving *C*) has twisted edges and the Harvey ribbed washer (Engraving *K*) has faces with ratchet-shaped ribs, to cut into the nut and splice bar and lock the nut when it is screwed up. The Eureka nut lock (Engraving *M*) is a square plate slit through to the aperture and spirally bent or warped with the edges of the slit upturned to lock the nut. The Automatic Rail-joint Spring or spring nut (Engraving *D*) is a heavy spring-tempered curved strap arched $^3/_{16}$ to $\frac{1}{4}$ in., according to size, tapped for the bolt and placed with the concave side against the splice bar. The aperture for the bolt is at a point about one-third of the length of the strap from one end, leaving an extending spring or tail longer on one side of the nut than on the other. The application of the spring to a rail joint is shown in the illustration of a 4-bolt splice, two of the bolts being put through the splice from one side and two from the other side; although all of the bolts can be put through from the same side of the rail if the spacing of the bolts permits. A square-headed bolt is used, and as the bolt is turned from the opposite side of the rail the spring is drawn down until it lies practically flat against the splice, as is the case with bolt No. 3 in the engraving. The primary action of the spring is to take up any wear of the parts of the joint and to compensate for any stretch of the bolts. Each spring or nut exerts an elastic pressure of 3000 lbs. The secondary action of the spring is to lock the bolt, since by the tendency of the spring to resume its normal shape the tail end exerts a pressure tending to give the bolt a sidewise twist or side bite, thus locking it.

Among lock nut devices one of the best known is the Harvey "grip thread bolt" (Engraving *R*). The bolt is made of soft steel and the threads are cold pressed in a manner to upset the metal and reduce but slightly the diameter of the bolt at the root of the thread. The threads are ratchet-shaped and undercut 5 deg. on the bearing side. In the nut the bearing side of the thread is at right angles to the axis of the aperture, so that when it is screwed up tight against the splice bar the threads of the bolt will give, to the extent to which they are undercut, and the metal will be pushed compactly into the outer recesses of the nut thread and hold the nut against turning off. The nut is square, with the corners chamfered next the wearing face to give a bearing which is approximately circular. On the bearing side the nut is recessed the depth of two threads to a diameter somewhat larger than that of the threaded bolt, thus housing and protecting that many threads against injury by chafing on the splice bar, as already explained. The National "elastic nut" (Engraving *S*) is split open on one side, being formed from a flat steel bar bent around into a ring to close by a lap joint. It is then pressed in a hexagon die and tapped slightly smaller than the bolt, so that when screwed on with the wrench it is distended and the joint opens about $^1/_{64}$ in., the spring action developing a grip on the bolt. The Oliver lock nut (Engraving *T*) is made some thicker than the ordinary nut and two or three turns of thread in the outer portion of the nut are cut at a slightly different angle from those of the greater portion of the nut and of the bolt. The locking of the nut is accomplished by the slight rupturing of the thread due to the gripe of the threads of differing angle. As this rupturing effect takes place on the outer end of the bolt no element of strength is sacrificed and the usefulness of neither nut nor bolt is destroyed by taking off the nut. The Young "gravity" lock nut (Engraving *N*) is an oblong jam nut tapped near one end. After the ordinary nut is screwed home the jam nut is put on and the overbalance of metal holds it against turning back. The nut-lock devices most extensively used are perhaps the double Excelsior, the National, the Verona and the Harvey grip bolt.

The devices above mentioned constitute only a small fraction of the nut locks which have been tried. Only a few kinds have been found efficient for the purpose, and none that has as yet come to general notice or into extensive service seems to have been entirely satisfactory. A number of years ago Mr. H. W. Reed, master of roadway for the Savannah, Florida & Western Ry. (now Atlantic Coast Line R. R.), found the average yearly expense for tightening bolts on 600 miles of track without nut locks to be $12.43 per mile, while with nut locks the average yearly expense for the same item was $4.00, labor at $1.00 per day. One trouble with spring nut locks, in numerous cases, has been the deterioration of the elasticity, in use, the device then becoming a dead flat washer. Another serious trouble with elastic washers of the narrow ring type, when used on splice bars with elongated bolt holes, is that they get jammed into the holes and their efficiency is lost for want of bearing. For the best results both nuts and nut locks should find an even seat all around the bolt. For this reason the bolt holes in the splice bar against which the nuts are screwed are frequently made circular and but slightly larger than the bolt, as already noted.

After all, the efficiency of track bolts depends largely upon the fit of the nut. A snugly-fitting nut, with or without a nut lock, will not work loose. In careful examinations of nut locks in service I have frequently found long stretches of track where all the bolts, provided with spring nut locks, had remained tight without attention, while on an adjoining piece of track, with the same nut locks in use, a large percentage of the bolts would be loose. The only explanation of the difference seemed to be that the tight bolts had snugly-fitting nuts, while the loose bolts had not, and that, apparently, the nut locks had played but little or no part in keeping the nuts tight. The production of loosely-fitting bolts and nuts is frequently due to the wear of dies and taps in too long service.

9. Spikes.—Track spikes should be made of good, tough material, so that the head will stand driving down upon the rail flange without breaking off. Both soft steel and wrought iron are the materials used, the latter principally for the reason that old iron rails are still to some extent being worked up into spikes. The Union Pacific R. R. owns a mill, located at Laramie, Wyo., in which a great deal of wrought scrap, including old iron rails, is made into spikes, bolts, angle bars and bar iron.

The standard size of spikes is $^9/_{16}$ in. square and 5 or $5\frac{1}{2}$ ins. long under the back of the head. For oak and other wood equally hard a length of 5 ins. is sufficient. The weight of a $5\frac{1}{2}$x$^9/_{16}$x$^9/_{16}$-in. spike is about $\frac{1}{2}$ lb. The head is usually made oblong, about $1^3/_{16}$x$1\frac{1}{2}$ ins., the under side of the same being inclined to correspond to the slope of the top side of the rail flange, which is usually 13 degrees. The standard spike point is wedge-shaped and its length varies from $\frac{3}{4}$ in. to $1\frac{3}{4}$ ins. The exact length, within these limits, is unimportant, so long as it is sharp on the cutting edge and not too thinly drawn out. For hard wood a point about twice as long as the thickness of the spike does very well. In seasoned white oak ties a long, slim point is liable to bend in driving and crook the spike. Spikes used in fastening rails to longitudinal timbers, as at pit cattle guards, have the point reversed, or turned quarter way around, so as to cut crosswise the grain and not split the timber. To strengthen the spike against wear from the rail, in the neck (a spike so worn is said to be "goose-necked"), it is the practice with some roads to slightly enlarge the cross section just under the head. Such reinforcement should not be made to the front or wearing side, because it would then operate to bend the spike outward when the head is driven down to the rail, and should the spike work up it would stand clear of the rail or permit the rail to spread slightly. If the reinforcement is made to the sides it interferes with facility of claw-bar operation. If reinforced at all the extra metal should be on the back side, but some object to any reinforcement to that side, on the ground that such would displace wood fiber which would remain out of contact with the spike, thus weakening its back support, should the spike work up.

The plain hook-headed spike of square cross section, above described, is standard practically everywhere in this country, and it is perhaps needless to say that for general purposes it is the best. Numerous attempts have been made to obtain greater lateral resistance, and increased adhesion, by the use of flat spikes, and spikes grooved at the back to give increased frictional surface, but all such experiments seem to have met with little success, and the spike of square cross section has held the field to the exclusion of all others. It was found that flat spikes were easily bent by the thrust of the rail, and spikes grooved to increase the adhesion cut open the fiber in such manner that water easily found its way into the fiber adjoining the back of the spike. Spikes of oblong section are difficult to catch with a claw bar and in hard timber they bend easily in driving.

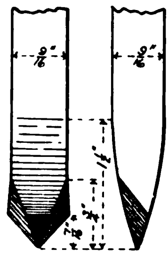


Fig. 22.

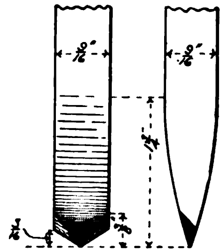


Fig. 23.


Fig. 24.

About the only improvement in the shape of the spike which has come into considerable use has been made in the shape of the point, the aim being to produce a point which will enter the tie without excessive injury to the fiber. The ordinary wedge point is formed in two ways: it may be cut with a die or it may be drawn out by rolling. When made by the former method the point is sharp, but frequently fins are formed on the corners which cause the spike to turn in driving. The rolled point is usually longer but dull or blunt on the cutting edge. The sharper the point the better is the satisfaction both as to ease of driving and in doing less injury to the fiber of the wood. The Goldie spike, made of soft steel, has a wedge point $1\frac{1}{2}$ ins. long, with corners beveled to sharp cutting edges, as shown in Fig. 22. The front side of the spike, as shown in the engraving at the left, is the wearing side. On this side the beveling extends $\frac{3}{4}$ in. above the extreme point and on the back side $^7/_{16}$ in. high. A side view of the spike is shown at the right hand in the figure. The standard spike of the New York Central & Hudson River R. R., for Carolina pine ties, is patterned closely after the standard spike of the Pennsylvania R. R., which is made of soft steel, is $5\frac{1}{2}$ ins. long under the head, $^9/_{16}$ in. square, in section, and has a rolled wedge point $1\frac{3}{4}$ ins. long, blunted on the extreme edge. The spike used by the New York Central company differs from that of the Pennsylvania company by being pointed at the tip on the Goldie style. The corners of the wedge on the front side are beveled for a length of $\frac{3}{8}$ in. and on the back side $^3/_{16}$ in., as shown in Fig. 23. In other respects the spike is exactly like the standard of the Pennsylvania road, having a neck enlarged on the side next the flange of the rail, the thickness front to back being $^{11}/_{16}$ in. The head is $1\frac{1}{4}$ ins. long and 1 $^5/_{16}$ ins. wide. The standard headblock spike of the Pennsylvania R. R. is like the standard rail spike except that it is 7 ins. long. The Diamond spike, shown in Fig. 24, has a gouge-shaped point, the face on the rail side of the point being convex, while on the back side of the spike (right-hand engraving) the face of the point is grooved. Screw fastenings are discussed in a later chapter.

10. Ties.—The selection of cross ties for track on roads of considerable length is a large and important undertaking. In this, much dependence may lie in the situation respecting the supply of timber in the locality. In timberless regions far removed from sources of supply there is usually a wide range for selection among timbers brought from a distance; while, on the other hand, where timber is abundant it is usually found to be more economical, all things considered, to use the best that can be obtained near at hand. It is between these two extreme situations, perhaps, that the most study is required in order to determine what particular kind of timber will be the most satisfactory. The cost of transportation, time required for delivery, and kindred questions increase the scope of investigation when ties are purchased at points off the railroad company's lines. The principal desideratum with ties is, of course, length of service at economical cost.

Conditions Affecting the Life of Ties.—The life of ties depends upon so many things that it is difficult of close estimation from knowing only the kind and quality of the timber. A good deal depends upon the season of the year in which the timber is felled. It is generally conceded that the proper time to fell timber is while it is free from sap. When timber is cut in the sap it will season leaving the sugar and albumen of the sap in the solid state, which will ferment and hasten decay when left to the action of water and variable heat, as is the case with timber used for ties. Also, when sap is in the timber the fibers are more open or porous than otherwise, which makes it more receptive of water from the outside than when the sap has declined naturally; and it is thought that when seasoned in this condition the pores do not close so tightly as with timber seasoned after the sap has declined. For this reason the holding power of spikes may depend to some extent upon the condition of the timber with respect to the presence or absence of the sap when it is felled. At all events it is commonly supposed that a mechanical change takes place in the condition of the fiber during the time the sap is out, which leaves the timber in a condition best suited to endure the action of the elements; and that at some particular time this condition is most favorable. On this time the opinions of good authorities vary all the way between the time just after the sap has declined until immediately preceding the time it starts again. Where some special use is to be made of the timber the determination of this particular time for the locality with some degree of exactness may be worthy of close study; but with ties it is hardly a practicable proposition to attempt to realize the desired condition so nearly as to specify a period as brief as a month or six weeks. It usually occurs, that, within reasonable limits, the time must be arranged to suit the convenience of the parties cutting the timber. In many localities a large portion of the ties are got out by farmers who own patches of wooded lands, and thus employ themselves during their spare time in winter. And then, too, the best time to cut probably varies with the kind of timber, and certainly with the climate or region. For the north half of the United States the time between late October and early March will include the tie-cutting season of perhaps all localities, and January is probably the proper time in most cases.

Ties cut during any month should be allowed time to season before they are put into the track. This rule is often repeated, but in practice it seems to be but little heeded. Those who profess to be authorities on the subject claim that at least six months is required to season timber well in the open air, and that a year is all the better. So far as ties used in renewals are concerned the most favorable time for cutting the timber and the most desirable time for placing the ties in the track are rather too close to admit of thorough seasoning of the timber, unless it is held over until another year; and such an alternative is, of course, out of accord with penny-wise policies regarding the investment of money. To let timber stand a year to season involves an interest charge of two to three cents per tie, which falls, of course, upon the railroad company, the matter being of no interest to the tie men. The tie-renewing season begins but a few weeks after the tie-cutting season ends and, as a matter of fact, a large amount of green timber is used in renewing ties. In building a new road it frequently occurs that any and all sources of supply are called upon, on short notice, and consequently much green timber and sometimes summer-cut timber, is used for ties. To aid the seasoning process the timber should be worked up into ties and peeled soon after felling. The hewing or sawing of the timber hastens evaporation of the moisture and the stripping of the bark prevents "souring" or fermentation. Timber experts say that bark should not be left on timber longer than two months after felling. The decomposition induced by leaving the bark on timber too long after felling, before the tie is made, is what the Germans call "suffocation."

In no case should ties be placed in the track before the bark has been removed. If they are not purchased with the bark peeled it will pay to have it taken off at the expense of the company. For such work a drawshave is a convenient tool, and track shovels and bark-peelers' spuds are also used. Ties peel easiest after being taken out of water, as when they have been floated in streams, or after a rain. The cost of peeling is 1 to 1½ cents per tie. With certain kinds of wood the presence of the bark after cutting favors worm eating; and with all kinds it is an absorbent of moisture, and will keep the sapwood of the tie damp as long as there is the least moisture in the ballast, thus hastening rot. Bark when dry is more inflammable than the timber in the tie and therefore renders the tie much more liable to take fire from sparks. After the tie becomes old the bark will loosen and mix with the ballast, much to its deterioration. It makes weed cutting between the ties more difficult, and, in short, it is so much of a nuisance that it should never be permitted in the track.

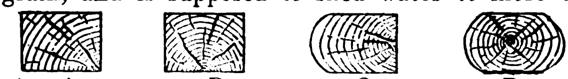
According to the general understanding the most durable timber is obtained from mature, but still sound and growing, trees, being superior to that cut from either young or very old trees. The disparity with the young timber is due to the relatively large amount of sapwood contained. It is also pointed out by authorities on timber that the location of the forest and the rapidity of growth have much to do with durability; that coniferous woods of slow growth (as indicated by narrow rings) on comparatively poor soil on high land, in dense forests, and hard or deciduous woods of rapid growth, from rich, deep, warm soil in the lowlands, but sparsely grown, yield the most durable timber of either class. The heavier and denser wood in the same species is the more durable. However much importance attaches to such conditions respecting the growth of timber, and even to the age of timber, for that matter, they have always been largely, if not entirely, overlooked in the selection of ties in this country. So far as age is concerned the "pole" tie or one faced on only two sides and made from a tree no larger than will yield one tie from a single cut, takes the preference. One reason for this is that the heart is in the interior of the tie and the sapwood on the faces occurs only at the edges of the same. Another reason is found with the advantages in the shape of the pole tie. The cheeks or rounded sides of the tie, from the center line downward, afford some bearing upon the ballast between the ties, and the weight of the filling material or ballast bearing upon these cheeks from above assists in holding the tie in position, making it more secure against being moved out of line or "churned" in the ballast than is possible with a tie sawed four-square. With some roads (one of which is the Buffalo, Rochester & Pittsburg Ry.) nothing but pole ties are standard, ties sawed on four faces, of whatever size or quality, being received only as second class.

Ties of any kind of timber resist decay longer in the colder countries, where the ground is frozen during several months of the year. For example, the average life of winter-cut white oak ties grown on high ground in Kentucky, Tennessee and Mississippi, and used on the Illinois Central R. R., is, by official statement, 7½ years on high ground in the states where they are grown, 10 yrs. in Illinois and 11½ yrs. in Northern Iowa. White oak ties grown and used in southern Arkansas last but 4 years, on the average, while ties of the same timber, grown in the same locality, when used in northern Illinois and Wisconsin, have an average life of 8 years. In the warm climate of southern Arkansas the timber is filled with sap at all seasons of the year, and ties cut therefrom are necessarily in sap. Under the continual action of the heat and moisture of the southern climate the process of decay is rapid, while in the northern states referred to, where the ground is frozen three or four months of the year, chemical change is entirely arrested during that time, and more or less retarded during other of the cooler months. Prolonged wet seasons shorten the life of ties, especially where the climate is hot. The life of ties varies with the kind of ballast used, to a large extent, being longer, for a usual thing, in those kinds of ballast which dry out most thoroughly and quickly. In loose material, like sand, gravel, broken stone or cinder, the exterior of the tie decays sooner than it does in compact material like clay, which is probably due to the condition respecting the exclusion of air. The chemical properties of the soil or ballast also have an influence on the life of ties. It is commonly understood that the effect of cinders is to shorten the life of ties. On the other hand, in 1901 there were ties in the track of the Central Pacific road, in salt and potash soils, in parts of Nevada and Utah, not the least bit decayed, which were laid when the road was built, in 1868. Ties of the same kind of timber in light, sandy loam roadbeds rot out in 3 to 4 years

Hard ties in stone ballast are hammered by the rail, and soft ties are rail cut, either action shortening the life irrespective of the destruction of the fiber by rot. The driving of many spikes into a tie, or a single spike redriven several times, mutilates and destroys the material of the tie just where it is put to the most severe service; so also does the grinding action of sand where it is habitually used, as on grades, near stations, etc. Ties of some kinds of timber check on the upper face from the heat of the sun and such open cracks get filled with sand or dust. Then when the tie gets wet the water gets in and is held by the earthy material to start decay in the interior sooner than otherwise. All these conditions, where they obtain, have to do with the life of ties. Good drainage lengthens their life.

A great deal of misleading data has been published on the life of ties. As a rule, the average number of ties placed in renewals per mile of track per year, reported by the railroad companies without qualification, is not a reliable basis for estimating the average life of the ties removed, because account is seldom taken of new road and sidetracks built within a back period corresponding to the life of the ties. When estimated on such figures the apparent life of the tie is too long, for it is clear that new track increases the mileage without increasing the renewals for a number of years. In estimating the life of ties from the renewals no track should be included on which renewals of ties have not been started, and, properly, no track on which the ties have not been renewed during at least three consecutive years, because during the first two or three years after the ties begin to fail the renewals are unusually heavy. On such grounds it would seem, therefore, that no track less than 7 to 12 years old, according to the quality of the ties, should be considered. As it is usually desired to know the average life of ties for main-track service, separate account should be kept of those used in side-tracks, where the timber is allowed to reach a more advanced state of decay before removal than would be safe for main track. In a general estimate on the life of ties, including all kinds of timber used for that purpose in this country, in its natural state, the average duration is usually taken at about 6½ years.

Manner of Cutting.—The advantages inhering with the pole tie have already been explained, and the same may be claimed for ties of any regular shape which conduces to anchor them in the ballast. In some of the European countries it is the practice to chamfer the upper corners of the tie, so as to narrow the face and reduce the supposed rocking motion claimed to be set up by the undulations in the rail. Such practice is badly advised, because under rolling loads the roadbed undulates with the rail and the rocking of the ties in the ballast is inappreciable; and besides, reduction in the width of the upper face without the use of tie plates removes fiber needed to resist rail cutting. Ties made from small trees are usually hewed, while from large trees they are sometimes split, but most frequently sawed. It is widely claimed that hewed ties last at least a year longer than sawed ties of the same quality of timber. One explanation for the inferiority of the sawed tie is that the faces are cut obliquely to the grain, exposing the ends of a great many fibers, which are roughened and started to a considerable depth, so that water is readily absorbed in wet weather. A hewn face is smooth, usually follows the grain, and is supposed to shed water to more or less extent



A B C D

Fig. 25.

for at least a year or two. For the purpose of smoothing the faces and making all ties exactly the same thickness (an unnecessary refinement), it is the practice in some mills to take the ties as they come from the saw and run them though a planer, surfacing two sides. Another objection to sawing, and one which is not overcome by planing, is that ties sawed out of crooked logs may be so crossgrained as to easily break in two under load or split in spiking. On split ties the faces naturally follow the grain of the timber, but some hewing is usually necessary to take out the wind at the rail seats. A sawed face affords an even bearing for both rails, which is not so liable to be the case with a hewed or split face. In ties sawed or split out of large trees it is not an easy matter to detect old timber, timber felled out of season, or even timber which was dead at the time of felling. In point of fact the timber worked up at saw mills, unless felled under contract at a specified time, is usually felled at any and all seasons of the year.

There are various conventional terms to denote the different ways of working up large timber into ties. When a log is sawed or split into four pieces, so that the heart is divided, each tie will have a piece of the heart at or near one of its corners, and is known as a "quarter" tie. When a log is sawed or split into two pieces each piece is known as a "slab" tie, if the heart comes in either top or bottom face, and a "half" tie if it comes in a side face. In Fig. 25, *A* is a quarter tie, *B* a slab tie, *C* a half tie and *D* a pole tie. Tie *C* is shown faced only three sides; if faced four sides it would still be called a half tie. The half tie is more liable to split in spiking than is a slab tie, for the reason that the spike enters the wood tangentially to the rings. Ties made from large timber should be laid heart side down, thus disposing the rings of the timber to shed water. The heartwood of most kinds of timber offers more resistance to rail cutting and holds the spike better than the sapwood, but it checks worse when turned up to the sun and the sapwood does not last so long in the ground. When the heart side is up the rings of the timber dip or open out, like troughs, and hold water. With pole ties the wider face should usually be laid downward. In cutting up large trees there is economy of lumber in sawing or splitting ties to rectangular section, and as an article of freight ties of that shape weigh less and occupy less space than pole ties having the same width of face. Under other considerations, however, it is inadvisable to face small timber four sides for ties, not alone because of the advantages already pointed out for the pole tie, but for the further reason that weight is a desirable property in track material, on account of the increased stability it gives.

Crooked timber should not be hewed into belly-shaped ties. With such timber it is better to make the faces straight, even though somewhat across the grain and though the tie be narrow-faced in the middle or at the ends. There is no particular objection to a crook in the tie horizontally, if not too much so. Ties, however made, should not be put into the track belly up, for a tie bulging upward in the middle of the track presents an ugly appearance and forms an obstruction to tear loose dragging brake rigging and pieces of car trucks; and such a tie is difficult of removal when it must be taken out. When a tie is put belly downward in dirt ballast its bed forms a sort of receptacle from which the water does not run freely after a rain.

Tie Dimensions.—The most common length of tie for standard-gage track is 8 ft., but since heavier rolling stock and heavier rails with wider bases have come into use many railway companies have increased the length to 8½ ft. For a tie of given thickness there is some certain length which conduces to a uniform distribution of rail pressure over the whole length of the tie. The experiments of Mr. A. Wasiutynski, permanent way engineer of the Warsaw-Vienna Ry., described under "Rail Deflection" (§ 181, Chap. XI.), show that such a length for white oak ties 6 ins. thick lies somewhere between 8 ft. and 8 ft. 10 ins. One of the general improvements carried out on the Prussian State and Imperial roads during recent years is an increase in the standard length for ties, both wood and metal, from 8 ft. 2½ ins. to 8 ft. 10¼ ins. (2.5 to 2.7 meters). In dirt ballast, where the ends of the ties must be exposed to insure proper drainage, a tie 9 ft. long seems to answer better than one of shorter length, since more support can then be given the track outside the rail and lessen the tendency to center binding, which is more pronounced with track in dirt ballast than in other kinds of ballast. Ties of such length are standard on a number of roads. Whatever the standard length, the specifications should be closely enforced. A variation of more than an inch either way ought not to be allowed, as there is no necessity for it. Where the ties are of uniform length the track is more evenly supported than is the case where the lengths vary. To give both rails equal support the middle of the tie should be at the center of the track, and if the lengths be not the same, or nearly so, either this condition cannot obtain or the ends will be out of line and cause a bad appearance. Still, where the ties are of irregular lengths it hardly improves the appearance of things to line one side, because then the track looks one-sided. The care usually taken to put the ends of ties to line on one side would, if the ties were approximately of equal length, secure fair line on the other side also, without extra trouble or expense. The habit of cutting ties to vary from 3 to 6 ins. from a standard length is slovenly and inexcusable, and the party who should pay for the consequences should be the individual who makes the ties, and not the railway company. The specifications of some roads require that ties more than 1 in. shorter than standard shall be rejected, on the first-class scale, and those more than 1 in. longer than standard length shall be cut off before they are received. The ends of ties should be cut with a saw, and reasonably square.

Besides being of equal length ties should be of uniform thickness, or nearly so. Ties varying much in thickness make an uneven rail surface for the outfit train to run upon during construction, unless considerable shimming or surfacing be done at a time when there is little opportunity to do it; and when not done there is danger of damaging the rails. The right thickness is about 6½ ins., and a variation of more than ½ in., at the most, should not be allowed. A tie much less than 6 ins. thick will be lacking in stiffness, and it is liable to be split when the spikes are driven, because the spike reaches so near to the under face. On the other hand a thickness of more than 7 ins., with ordinary tie spacing, interferes with facility in the use of the tamping bar. In pole ties extra depth narrows the faces, a difference of 1 in. in depth making a considerable difference in width of face. To allow for strength in the case of ties longer than 8 ft. and for both strength and for rail cutting in the case of soft wood ties, it is well to give such ties the benefit of the maximum allowable thickness. On a few roads soft wood ties are made as thick as 8 ins., but on a great majority of the roads the standard thickness of ties of all kinds of timber is either 6 or 7 ins., but perhaps more often 7 ins. than 6 ins. As touching the matter of strength a slight variation in the thickness of the tie makes a large difference. Since beam strength varies as the cube of the depth or thickness the relative strength of a 7-in. tie to that of a 6-in. tie of the same width, is as 343 to 216, or 59 per cent greater.

While there is neither difficulty nor reason why all ties should not be of the same length and thickness, it is not always so with regard to the width of face; neither is it so necessary that it should be. There is much said concerning the arrangement of ties in track with reference to uniformity of width of face that is to no great purpose. As long as there is no tie with a face narrower than a minimum acceptable, and the variation in width of face among all the ties is not greater than 50 per cent, it is hardly worth while to waste words with the tie maker or to consume time trying to arrange ties of the same width of face to go into the track together. Ordinarily about 40 per cent of the surface of the rail base rests upon tie face, and of course the same proportion of the surface of the ballast can be covered by tie face, be the ties large or small, so long as they are properly spaced. By spacing ties a certain distance apart in the clear (as they should be), and not a certain distance apart center to center, and increasing the width of the spaces next the largest ties, in case they are abnormally large, the bearing surface of the ties will be about equally distributed along the rail. A rough estimate in adjusting the spaces, by the eye, even where a considerable variation in width of face exists, will not appreciably depart from the proper proportion of bearing surface. Where the ties are small there are more, and where large, less, of them for a given length of rail, and consequently about the same amount of bearing surface in either case.

A 6-in face for pole ties and an 8-in. face for ties of rectangular section is the minimum allowable for main track. Smaller ties, bought at a reduction in price, may answer in side-tracks; but enough for this purpose may usually be had in culls from the whole lot offered for sale, because quite frequently a small tie must be made from the top of the tree in order to avoid undue waste of timber. But there is also such a thing as a tie too wide to give good results. Wide ties are seldom tamped as firmly as they should be; and it is somewhat difficult, also, to do it properly without using time much out of proportion to the size of the face. A tie having a face exceeding 10 ins. in width is too large for main track. The width of face giving best results all around is 8 ins. for pole ties, and 9 ins. for ties of rectangular section.

Kinds of Timber.—Oak, pine and cedar are now the timbers principally used for ties. White oak, rock or bur oak, post oak, chestnut oak and red oak are the varieties used. White oak is the timber which gives the best all-around results. Of the durable woods, when seasoned, it holds a spike the firmest, and, except under very heavy traffic, it supports the rail without being cut into until after it is well along in decay. Its life, stated in a general way, is from 5 to 10 years, depending upon circumstances, some of which have already been noted. A general average of the average life of white oak ties reported by 22 well-known railroads of the northern states, located both east and west of the Allegheny mountains, is 8¼ years. The figures taken into account in this average were supposed to represent the life of ties which had failed by natural decay and not by rail cutting. In the southern states the life of white oak ties seems to average 5 to 6 years. The weight of a 7x9-in. seasoned white oak tie 8 ft. long, sawed on four sides, is about 185 lbs.; of a 6x8-in. tie of the same length and sawed in the same manner, about 140 lbs.; of a white oak pole tie 8 ft. long, 6½ ins. thick, with 8-in. faces, about 175 lbs. The toughest and best quality of white oak, when green, takes on an inky blue color when cut across the grain. The other kinds of oak are not so good. Rock oak comes next best. It is hard, but not quite as tough as white oak, and its life is about the same. Red oak is more brittle and softer, not holding a spike nearly so well as either white or rock oak, and its life is not more than half that of white oak, sometimes lasting not more than three years. It makes excellent material for shims on account of its straight grain and ease of being split without shattering. It is subject to worm eating. Oak ties are used throughout the Allegheny mountains, in the middle Atlantic states, in the lake states, and in the Ohio and Mississippi Valley states. In 1900 it was estimated by good authorities that the different varieties of oak ties comprised about 50 per cent of all ties in service in this country; ten years earlier the estimate was 60 per cent.

In the south Atlantic and gulf states southern yellow pine ties are used extensively, and late years large numbers of them have been shipped into the middle Atlantic and New England states. The life in the South is 4 to 6 years and in the North 8 to 12 years. In the white sand ballast of some of the roads in Florida these ties last but 4 years and on the Isthmus of Panama but 1 to 2 years. In western Texas, New Mexico and Arizona a mountain pine is largely used for ties, but it is inferior to the southern yellow pine, lasting only 4 or 5 years when laid in the natural condition; when treated with zinc chloride such ties last 8 to 12 years or longer, as witnessed by the experience of the Atchison, Topeka & Santa Fe Ry. (§ 168, Chap. XI). California mountain pine is of better quality. In the gulf states black and red cypress are used to a considerable extent. It is a soft timber, requiring tie plates for best results. The natural life, as reported by some roads, is 10 to 12 years.

The most durable timber for ties, so far as resistance to decay is concerned, is cedar. Both red and white cedar are the varieties available, but the supply of the latter is much the more abundant. It is a very soft timber and is cut into by the rail so rapidly that it is sometimes taken out, turned over, and put back long before there is any sign of decay. It is used to best advantage on straight-line track under light traffic. Under heavy traffic it does well on tangents if tie plates are used, the life of cedar ties, when so protected, being 15 to 20 years, and even longer. In fact the natural life of cedar ties seems not to be widely known, if known at all, because in nearly every case where such ties have failed the cause has been either rail cutting or spike killing. On the Saginaw division of the Michigan Central R. R. there are large numbers of cedar ties which have been in service more than 19 years, and the ties are still in sound condition and expected to last 10 years longer. Tie plates were not used on these ties until after they had been in service 18 years. On the Buffalo division of the Buffalo, Rochester & Pittsburg Ry. there are cedar ties in the track which have seen service for 17 years and are in condition for further use. There is on record the case of a red cedar tie which did service in the track of the Boston & Providence (now New York, New Haven & Hartford) R. R. from 1834 to 1876 or 42 years. Sound, dead cedar gives just as satisfactory service as live, green cedar, which is a fortunate circumstance, for the bark of cedar trees is thin and over large areas of cedar forests which have been swept by fires the trees have been killed. The supply of cedar ties in this country is obtained largely from Canada and from states along the Canadian border, such as Maine, Michigan, Wisconsin, and Washington. Cedar is light in weight and is carried farther for ties than any other timber. When used with tie plates it is considered to be a very economical tie timber. On the behavior of cedar ties under traffic, and the use of tie plates with the same, the reader is referred to a comprehensive article entitled "Cedar Ties in Service," written by Mr. Moses Burpee, chief engineer of the Bangor & Aroostook R. R., and published in the Railway Review of March 13, 1897. Spikes hold best in cedar ties when driven in the sap, or as close to the edges of the tie face as good practice will permit.

The average life of chestnut ties is about 7 to 9 years. Chestnut timber is medium in hardness and holds a spike quite well. It is found quite abundantly in the middle Atlantic and New England states and is there much used for ties, telegraph poles, and fence posts. It is disposed to check badly in the sun. In the northern states east of the Mississippi river hemlock is used to a considerable extent for tie timber. It is soft, but holds a spike tolerably well. It usually rots from the outside in, and it will hold the spike quite firmly, sometimes, when so rotten on the outside as to be of no further use. The life of native hemlock ties is 4 or 5 years, but hemlock ties brought from Canada and used in New England last a year or two longer.

In California, redwood is extensively used for ties. It is soft but durable, and when green it is heavy. Redwood ties are usually split out of large timber. On the Southern California Ry. (Santa Fe System) redwood ties, used with tie plates, have been found in good condition after a service of 14 years. Without tie plates the life of this timber is measured by the traffic carried rather than by time. There are records of redwood ties in side-tracks on the Southern Pacific road, perfectly sound after 40 years of service. Farther up the coast, in Oregon and Washington, fir and white cedar are used. Fir, if first allowed to season, holds a spike well, and lasts 6 to 8 years in gravel ballast. In Montana ties are principally tamarack and cedar. In the Ohio valley wild cherry, honey locust and black walnut are used to a small extent for tie timber, and each lasts about 8 years. In Canada cedar, oak, tamarack, hemlock, spruce and fir are the tie timbers largely used, the average life of all except cedar and hemlock being about 8 years. Tamarack is a variety of larch (American or black larch) and in some localities is called hackmatack. Its durability is quite variable, for in some parts of Canada and the United States the average life is only about 4 years. On the Duluth, Missabe & Northern Ry. it lasts 6 years. In Canada the average life of hemlock ties is 6 years.

It is an easy matter, and useful as well as interesting, to so mark a tie when it is put into the track that at any time its length of service may be known. This can be done by simply cutting a notch in the edge of the tie face, in a certain position fixed for each year of a decade. Say the road runs north and south: then let the odd numbered years be marked on the north edge of the face and even numbered years on the south edge. Starting at the east end of the tie, let successive notches toward the west end thereof indicate years increasing upwards to ten. As distinct positions for the notches points can be taken outside the rail, just inside the rail, and at the middle of the tie, making positions for five notches on each edge of the tie face. With ties thus marked the foreman is able to take note of the ages of the ties removed when making his report on renewals. A system of notching something similar to that above described has been used on the Allegheny Valley Ry. On some roads, including the Southern Pacific and the Lake Shore & Michigan Southern, the ties are stamped when put into the track with a cast iron hammer having a raised figure on the striking face denoting the year. The figure is quite large and is raised about $\frac{1}{8}$ in. The usual practice is to stamp the tie in the end, on the line side, and sometimes also on the top. At the end of each year all the hammers bearing dies for that year are called in and scrapped and new ones are cast for the new year and issued to the section foremen. A better record, and one which has now come into extensive use, is a galvanized iron or copper nail with the last two figures of the year of laying stamped on the head. The nail is usually $\frac{1}{4}$ in. in diam. and $2\frac{1}{2}$ ins. long and the head is $\frac{5}{8}$ in. in diam.

11. Tie Plates.—Tie plates, or "wear plates," as they are known in Europe, are metal bearing pieces placed upon the ties to protect them from being cut by the rails. Rails cut into the ties by crushing down and abrading the fiber. The crushing action is due to direct pressure or impact and the abrasion takes place by the infinitesimal creep or sawing action of the rail in its wave motion under the traffic. The presence of grit on the ties, where it can work in upon the rail seat, as on grades or in yards where sand is used freely, augments the rasping or cutting action of the rail. Some students of the question ascribe the principal cause to the abrasion, while others go so far as to claim that it is the sole cause, of rail-cut ties. The symptoms, however, clearly indicate that rail pressure has considerable effect in cutting the ties; otherwise a thin sheet of metal would suffice for their protection. The fact that tie plates $\frac{1}{4}$ in. thick buckle in service disproves any assumption which ignores the effect of rail pressure. It is further to be noticed that the rail cutting of ties is most rapid at the joints, where the rail is weakest and rail pressure the most intense. The point is sometimes raised that tie plates do not greatly increase the surface over which rail pressure is distributed, and at first consideration this fact would seem to nullify the importance of rail pressure. It should be understood, however, that the ribs or under projections of tie plates assist materially in the support of the plate. It is a matter of common observation that tie plates placed upon the ties without being seated resist the pressure of the traffic for some time before they become fully settled into the timber.

As the object sought in the use of tie plates is to make the ties last during the natural life of the timber, the necessity for the same arises only where the ties would fail by rail cutting or spike killing sooner than they would become unserviceable from decay. Generally speaking, the conditions which decide this matter are the hardness of the wood and the intensity of the traffic. Thus, hardwood ties usually fail by decay rather than from wear, and, as a rule, the use of tie plates on such ties is not sanctioned in practice. In rare instances, where the traffic is very heavy, as in busy yards, but seldom on main track, the use of tie plates on white oak ties may be justifiable, but such cases are the exception. Under light or medium traffic softwood ties may give satisfactory service without tie plates, but under heavy traffic they usually need protection against rail wear, especially on curves. In this connection, however, it should be said that a great deal depends upon the weight of rail used. Increase in weight of rail lessens the tendency to cut the ties, in several ways: the increased hight and greater stiffness of the heavier rail distributes wheel pressure over more ties, and the wider base covers more tie surface, thereby reducing the unit pressure in two ways; while the decrease in wave motion, due to the increased stiffness, lessens the creeping of the rail and its rasping action on the wood fiber. Reflection upon this fact will account for the excessive cutting of ties in some busy yard tracks. The rails in such places are usually of light section and of second quality, or too badly worn for use in main track. Under these conditions the rail deflects heavily under the wheels, bringing excessive pressure upon the narrow bearing, and this pressure is further augmented by the hammering action of the wheels on the roughened running surface.

The natural life of the ties is also an important consideration in tie-plate economy, for it is clear that nothing is gained in applying tie plates to timber which rots out as soon, or nearly as soon, as it would cut out under the traffic without them: if only a year or two can be added to the life of the tie by their use it may not be worth the while to bother with them. The possibilities in the use of tie plates are greatest with soft timber which resists decay for a long time, such as cedar, redwood and cypress. Without tie plates such timber may not hold out half its natural life. Between these extreme cases there is opportunity and occasion for study, for while the use of the tie plate may add something to the life of a tie which, unprotected, can carry the traffic imposed without being badly cut until it is well along in decay, the question as to whether the saving so made will pay for the cost of the plate and the labor spent upon it is worth looking into. It is, however, a question easily determined, for if there be any doubt concerning the advisability of using tie plates, in any case, it is a matter of but slight trouble and expense to put them in the track for a few hundred feet and give them a trial.

The strictest sense of the limitations on the use of the tie plate, hitherto remarked upon, is intended to apply only to straight-line track, or to track laid with white oak ties or other ties equally as hard. For curved track laid with any but the hardest ties some exceptions to, or qualifications of, these statements may in cases be necessary. On curved track, especially where the curvature exceeds 3 or 4 deg., tie plates can sometimes be used to advantage, though the same ties on tangents would bear up well without them. As the tie plate ties the outside and inside spikes together the two or more spikes driven through the plate act in combination with the resistance of the plate against the spreading of the rail, whereas the spike driven on the inside of the rail where a plate is not used is of no effect in holding the rail against spreading. Tie plates, then, if of proper design, may serve as rail braces; and in fact they are frequently used in lieu of rail braces. The tie plate can also perform important service by preventing the inside rail of curves from canting. Where the ties on the curve are soft or where hard ties have become somewhat decayed, heavy, slow trains will sometimes cant the top of the inside rail outward (The cause for this action is fully taken up in a later chapter). While there is just the same tendency to cant where the tie plate is used, the outside edge of the rail flange cannot cut into the tie and thus tilt into a position in which the tendency for canting is increased. So far as curves are concerned it may be said that, as a general proposition, wherever trouble is had from spreading or canting rails the use of the tie plate is to be recommended. On a number of roads it is the practice to use tie plates on curves, regardless of the quality of the ties, but not on tangents. The idea is, of course, to maintain the gage and preserve the upright position of the rails. On other roads the use of tie plates, if at all, is restricted to curves of 3 or 4 deg. and over. When used on curves it is customary and also the best practice to plate every tie. It is the practice of a large number of roads using tie plates on tangents to place them on joint ties only.

The early idea of a tie plate was that it should be thick and heavy, and it was usually made smooth on the under side. Experience has developed changes in these respects, for economy of material compels a minimum of weight consistent with strength, and one of the most important considerations is to obtain a plate which will unite firmly with the tie; otherwise it will pound the tie and wear into it under rail vibration and afford no lateral resistance to spreading of the rails. As such a requirement cannot be met by a plate with a smooth under side, practically all tie plates are now made with under projections, in the shape of claws or flanges, which enter the tie and hold the plate fast. The claw type of under projection enters the wood crosswise the grain and the flange or rib type enters the wood longitudinally with the grain. In the former case the lateral displacement of the plate is resisted by an abutment against a section of the fibers, while in the latter case the displacement is resisted by the friction of the flanges in the wood, the idea being that the seating of the plate crowds and compresses the fibers of the wood in between the flanges, thus giving the plate a firm hold in the tie. One advantage with the longitudinal flange is the facility of moving the plate for an adjustment of the gage of the rails, since by striking the plate on the end the flanges may be made to plow their way through the wood. After a plate having claws (or other under projections) cutting crosswise the fiber is once seated it is not an easy matter to change it to a position slightly removed and seat it again firmly.

Respecting the wearing surface or rail seat of tie plates, various patterns are flat, grooved, corrugated and shouldered or provided with lugs. The advantages intended for the grooved top are economy of metal and provision for the escape of sand and dirt, which may work under the rail and, if not removed in some way, lead to undue wear to both rail

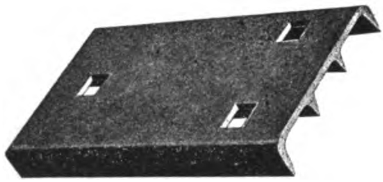


Fig. 26.—Servis Tie Plate.

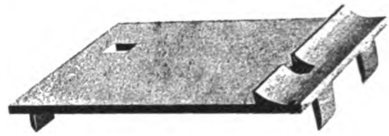


Fig. 27.—Goldie Tie Plate.

and plate. On the latter point of design authorities disagree, for there are those who claim that a groove or depression in the face of the plate serves to hold the grit and cause it to accumulate in larger quantity after once it begins to collect there, whereas the undulation of the rail over a flat-top plate will blow the grit away. The purpose of a lug or shoulder on the top of the plate is to receive the lateral thrust of the rail and save the neck of the spike from direct pressure and wear. With such an arrangement the lateral thrust of the rail is opposed by the resistance of the plate in the wood before the spikes begin to act, thus relieving the spikes of that much side pressure. There is also the further advantage that the pressure against the spike is received at a point nearer its bearing in the wood, thus acting at a shorter leverage than is the case where it is received above the plate; in other words a spike can hold more firmly against a tie plate than against the flange of a rail placed on top of the plate. One fault found with shouldered tie plates is that they do not permit shimming to be done crosswise the rails. For curved track the largest practice seems to favor a tie plate with a shoulder, and a shoulder extending across the whole width of the plate has the preference, as it stands wear better than a narrow lug. Shoulders or lugs not being required for the gage side of the rail are provided for the outside only.

One of the oldest and best known of modern tie plates is the Servis pattern, Fig. 26. It is made with or without lugs on the top, and the bottom has three or four longitudinal flanges, according to the width of the plate. It is rolled to a thickness of $^3/_{16}$ to $^5/_{16}$ in., and in widths varying from $4\frac{1}{4}$ to 6 ins. Another very well-known tie plate is the Goldie pattern, Fig. 27. It has a shoulder running the width of the plate and the under side has four claws set on the end edges, 1 in. inward from the sides. These claws are 1 in. wide and $\frac{7}{8}$ in. to $1\frac{1}{4}$ ins. long, as ordered, and have a sharp cutting edge. On the latest pattern the claws have a Goldie spike point (Fig. 22) and the claws are rolled to stand in under the body of the plate, thus protecting the opened fiber from the entrance of water. It is rolled of steel, $4\frac{1}{2}$ to 6 ins. wide, and $\frac{1}{4}$ to $\frac{3}{8}$ in. thick, according to demand. Another design, bearing a close resemblance to the Goldie pattern, is the Churchward, or better known as the "C. A. C.," tie plate. Like the Goldie plate, it has a shoulder about $\frac{1}{4}$ in. high

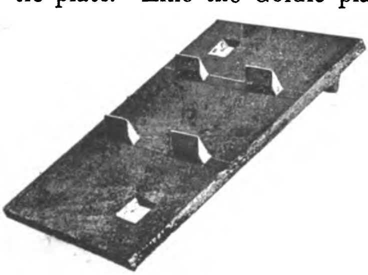


Fig. 28.—C. A. C. Tie Plate.

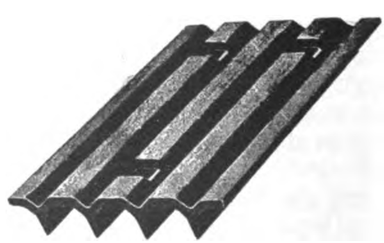


Fig. 29.—Wolhaupter Tie Plate.

and as wide as the plate, and on the under side (Fig. 28) there are four chisel-edged holding lugs or claws set in directly underneath the rail seat, where they receive the bearing of the traffic direct and where the fiber is well protected from the entrance of water. The plate is steel, about $\frac{1}{4}$ in. thick, and is rolled either flat or beveled, as desired, the intention of the latter style being to give the rail an inward cant, the purpose of which is explained under the subject of "Rail Design." The Wolhaupter tie plate (Fig. 29) is of rolled steel, with four longitudinal flanges on the under side and a corrugated top surface, the grooves of the corrugations coming over the flanges. The side flanges are set in under the edges of the plate and the spaces between the flanges are arch-shaped, so as to compress the fibers and hold firmly to the tie. The plate is made either with or without lugs to take the thrust of the rail. The metal is $^3/_{16}$ to $^5/_{16}$ in. thick. Another tie plate of an earlier pattern is the Fox, shown in Fig. 30. It is a flat plate with segments stamped down to form longitudinal flanges and provide holes for the spikes, and the top has a lug to take the thrust of the rail. It is in use, but not extensively.

Among tie plates of more recent design the prominent patterns have longitudinal flanges on the under side, and in all essential respects they are but variations of older forms, the chief aim being to distribute a

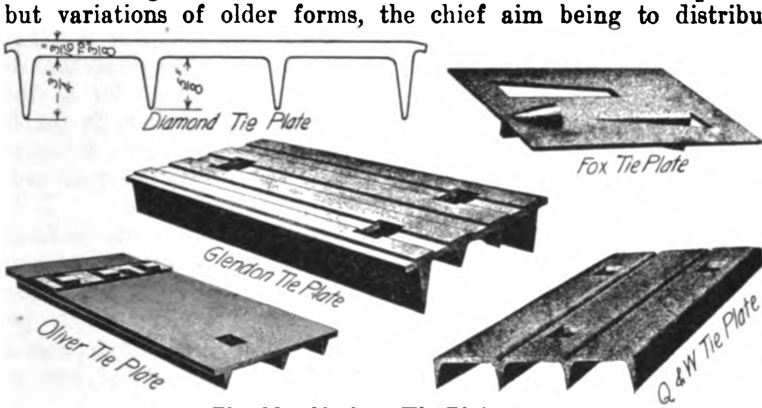


Fig. 30.—Various Tie Plates.

minimum of material to effect a desired strength or stiffness. On the Glendon "Flange" tie plate (Fig. 30) the top is grooved and the rail rests on bearing surfaces immediately over the flanges, the intention being to apply the load over the strongest parts. There is no rail bearing surface extending beyond the outer flanges. The plate is made in sizes from $4\frac{1}{4}$ to 6 ins. wide and $^3/_{16}$ to $\frac{3}{8}$ in. thick. The Q. & W. tie plate (Fig. 30) is a combination design, borrowing the side flanges of the Servis plate and the corrugated top of the Wolhaupter. The advantages sought are the economy of metal characteristic of the latter pattern and the adhesion of the former. The Oliver tie plate (Fig. 30) has short longitudinal flanges on the under side, a flat rail seat without depressions, and a transverse rib or shoulder extending across the whole width of the plate, to serve as a rail brace and prevent the rail from "necking" the spikes. The thickness of the metal is $^5/_{16}$ in. The Diamond tie plate (Fig. 30) has a plain flat top without depressions, the intention of the designer being to avoid the collection of cinders and sand. The plate is rolled in widths of $4\frac{1}{4}$, 5 and 6 ins. and in thicknesses varying by $^1/_{16}$ in. from $^3/_{16}$ to $\frac{3}{8}$ in., the $^3/_{16}$ and $\frac{1}{4}$-in. plates being the ones in largest demand. The $4\frac{1}{4}$ and 5-in. plates for intermediate ties have four flanges, as shown, the outer flanges being $\frac{3}{4}$ in. deep and the inner ones $\frac{5}{8}$ in. in depth. As with the Glendon plate, both sides of the flanges have the same inclination from the under surface of the plate, the intention being to equalize the pressure of the wood fiber on both sides, thus avoiding any tendency to distortion of the flange as the plate is driven to its embedment. Plates 5 and 6 ins. wide, for joint ties, have only three flanges, such being commonly in use where the specified punching would interfere with the inner flanges of the four-flanged plates. The sides of the plate have small hood projections extending beyond the outer flanges. The upper surface of this projection is beveled down, to prevent bearing from the rail outside the flange, and the under side is fluted to prevent water from reaching the opened fibers.

The distinctive features of the Hart tie plate, another of the later designs, are a cambered top and a corrugated top surface. The top of the plate is crowned or cambered without cambering the plate as a whole, which is done by increasing the thickness of the plate at the center. The corrugations begin near the median line of the plate and extend obliquely across the top surface, growing gradually wider and deeper as they approach the outer edges of the plate. The purpose of this feature of design is: First, to prevent the accumulation of sand on any part of the plate's surface; second, to carry off water, brine, acid or other drippings from the cars; and third, to add strength without destroying the fiber or grain of the metal, or causing crystallization of the metal in the process of manufacture. The bearing of the rail comes at the central portion of the plate, bringing the bearing upon the center of the tie, with the idea of avoiding any tendency to loosen the plate in the tie, or rock the tie from the undulations in the rail. The under surface of the plate is provided with longitudinal flanges, similar to those of ordinary design. It is illustrated in Fig. 549, Supplementary Notes.

It may be of interest to state further that some of the railroads of France are using a tie plate made of tarred felt, costing 1.6 cents and lasting from six to ten years. These, however, are being superseded by tie plates made of creosoted poplar wood, cut from the gnarly portion of the tree. These plates are about the thickness of a shingle, cost about .8 cent each and are said to be more economical than either iron or felt tie plates. The claim for these tie plates of soft material is that they take all of the wear, whereas the iron tie plate, in time, wears both the rail and the tie. The fact that tie plates of such material are serviceable might seem to belittle the importance of rail pressure as one of the causes of the rails cutting the ties, but it must be considered that in France, and in Europe generally, the rails are heavier and the wheel loads much lighter, as a rule, than they are in this country.

The most common width for tie plates is 5 ins. and the most common length 8 ins., 5x8 ins. and 6x8 ins. being the sizes most frequently found. A length of 9 ins. is not uncommon, and greater lengths come to notice occasionally. The minimum width in extensive use is 4½ ins. For softwood ties the plates should afford generous bearing surface and 5x8-in. and 6x9-in. plates are none too large for rails of heavy section, the latter size being preferred except where the face of the tie is too narrow to afford a good seating for the plate. In any case the plate should be somewhat narrower than the face of the tie. For pole ties an assortment of plates of both the widths stated works well. The tendency of practice is to reduce the length of tie plates to such dimension that there will be only ½ to ¾ in. of metal outside the spike holes. The experience with long plates is that they buckle and do not stand the service as well as shorter ones.

Tie plates are usually punched for two or three spikes, but for use on sharp curves they are sometimes punched for four spikes. If the margin outside the spike hole is wider on one end of the plate than on the other the plate (there being, of course, no alternative with shouldered plates) should be laid to bring the wider margin outside the rail. This arrangement assists the plate to oppose the canting tendency of the rail. In some designs the plates are punched that way purposely. The spike holes should be punched to allow for a close fit of the spike to the rail flange. To provide for this the holes are usually made large enough for $^1/_{16}$ in. play. In order to bring the spikes at the right edges of the tie on both rails it is necessary to punch two-hole plates as rights and lefts. In some cases plates are punched with four holes, so that they can be used on either side of the track; or they are sometimes punched with three holes for the same purpose—two holes on one end of the plate and one hole on the other end, in the center of the plate. The latter arrangement is not a good one, for ties, especially pole ties, should not be spiked in the center of the face. For joint ties the plates must be punched with reference to the width over the splice bars (supported joints) or to correspond to the slotting of the bars for suspended joints or long splices extending over three ties. It is often desirable to punch plates with two sets of holes, so that when new rails of different base width are laid it will not be necessary to move the plates. When such is done the margin of metal outside the outer spike hole should be such that after the change the projection of the plate outside the rail will not be less than that on the gage side. Further instructions regarding the punching and handling of plates intended for rails of two different sections are to be found in connection with "Laying Tie Plates," § 106, Chap. VII.

12. Ballast.—Ballast is material placed upon the roadbed for the embedment of the ties, and the following are its functions: (1) to drain water from the ties; (2) to provide a firm and even bearing for the ties and to distribute the pressure from the ties over the roadbed; (3) to provide against heaving by frost; (4) to supply filling material between the ties, to hold them in place, and against their ends to hold them in line; and (5) to impede the growth of grass and weeds in and near the track. Some essential properties of good ballast are that it shall not change to a miry consistence when wet, and it should not disintegrate upon exposure to the elements. A desirable property of the filling material is that it may be readily worked in renewing ties and surfacing.

Broken Stone.—The material which most nearly fulfills all the requirements of ballast is broken or crushed stone, commonly called "stone" or "rock" ballast. Some of the advantages to be gained by its use are: It distributes the pressure better than any other kind of ballast, the pieces of stone acting much like bricks in a wall. The area of support widens with depth, and at a less depth than with any other ballast the pressure from the ties is distributed uniformly over the roadbed. Being the hardest material (considered in the aggregate) used for ballast, it secures the track best against settling. It does not hold water, and if the roadbed is properly drained it does not heave in freezing weather. Clean stone ballast can usually be handled and worked in winter, or in wet weather, and it is not wasted by rain or wind. It is the cleanest material used for ballast, and when carefully dressed presents the neatest appearance; for which reasons it is usually preferred to other kinds of ballast by railway companies which depend largely upon summer travel for business. As long as it is kept clear of dirt, such as sand, dust, loam, cinder etc., it will not grow grass or weeds. Where such growth does get started, however, it is a difficult matter to get rid of it, for practically it must be pulled by hand.

While broken stone answers so well the many requirements of a good ballast, nevertheless in some respects it compares unfavorably with some other kinds of ballast. Its first cost is high and the cost of putting it under the track or of handling it in any manner with the shovel is much higher than the cost of similar work in gravel. It is more severe on ties and rails than gravel, and unless the track is kept in smooth surface stone ballast is hard on rolling stock. While it affords good drainage the sharp corners of the stones cut into the ties, and after the ties begin to decay they deteriorate by impact more rapidly than they do in gravel ballast. The cost of tie renewals, surfacing, and all repairs where the ballast must be handled over is high, running from 50 to 100 per cent higher than the cost of the same work in gravel or like ballast. At a convention of the New England Roadmasters' Association, in 1897, it was voted as the sense of the convention that the average cost of renewing ties in gravel ballast was 15 cents each and in rock ballast 21 cents each. In a low lift of the track in surfacing, broken stone ballast is not so easily or as satisfactorily tamped as is gravel or other ballast of finer aggregation. Wherever the lift in stone ballast is not as high as the thickness of the stones the ties cannot be properly tamped without breaking up the old bed, whereas in ordinary gravel or cinder ballast the ties may be tamped under a lift as small as $\frac{1}{4}$ in. without disturbing the hard bottom of the previous embedment. On this consideration, it is widely claimed that smoother surface can be maintained with gravel and some other kinds of ballast than with broken stone. Where ballast is not tamped to a uniform solidity the tendency for the rails to cut into the ties is much increased over that which obtains under normal conditions, and such is an objection sometimes raised against broken stone ballast. Referring to general practice, it is probably true that on stone-ballasted track there is a natural inclination to let minor defects in surface run longer without attention than is the case on gravel-ballasted track. It is also claimed that in lining track in stone ballast some difficulty is experienced in holding the rail to the exact spot, especially when it is lightly thrown, the reason being that the stones crushed into the bottom and sides of the tie will roll and carry the track some distance back when the first train goes over it.

The stone ballast most commonly in use in this country is broken or crushed to a size which will pass a ring of 2 ins. inside diameter. There is, however, a wide diversity in the sizes known to practice. One class of maintenance men, who think that the size stated is too retentive of fine material, causing the ballast to become dirty and compact, prefer a size as large as $2\frac{1}{2}$ or 3 ins., and there are a few who use it as large as $3\frac{1}{2}$ ins. On the other hand there are many who think that 2-in. stone is too coarse for even tamping, smooth surfacing and easy working, and with them the $1\frac{1}{2}$-in. and 1-in. sizes are in favor; in fact a good deal of experimenting is being done with stone broken to a $\frac{3}{4}$-in. ring. A general principle which governs to some extent is that the harder and tougher the stone the smaller it may be broken, as such material is not so easily crushed and reduced in size by working. The most usual size with European roads is that broken to a $3\frac{1}{8}$-in. (8-centimeter) ring, but $1\frac{1}{2}$-in. and 2-in. stone is frequently used.

Rock ballast broken in a crusher contains more dust and small pieces than that broken under the hammer, and the proportion of fine material increases with decrease in the size to which the ballast is broken. It is customary, therefore, to pass crusher-broken stone over a screen and take out the dust and finer particles. In some cases the product from the crusher is run over a series of screens, one or more to take out the fine material and another to separate pieces larger than the specified size. Thus, at a certain railroad plant the stone from the crusher passes through three revolving screens formed of perforated steel plate, the first having holes ½ in. in diam., the second 1 in., and the third 3½ ins., in diam. The size of stone used for ballast is that which will pass through the 3½-in. holes but not through the 1-in. holes. As a matter of information it may be said that the supervisors who are using this ballast think it entirely too coarse, being of the opinion that ballast of this size would be improved by omitting the 1-in. screen, or by using everything which passes over the ½-in. screen and through the 3½-in. screen. The stone broken up at this crusher is flint and limestone, and it screens out in the following proportions: 70 per cent 1-in. to 3½-in. ("No. 4") ballast; 17 per cent ½-in. to 1-in. ("No. 2") ballast; and 13 per cent stone dust, dirt, etc. passed through the ½-in. screen. It is understood, of course, that in all broken stone ballast the specified size refers only to the largest pieces, a large portion of the material in all cases being smaller than that size. In some specifications it is required that the largest stones shall go through the ring "any way they are put," which means that the specified size refers to the largest dimension. Some are opposed to screening out the small clean particles of stone more closely than is necessary in removing the dust and sand-like residue, claiming that ballast may be too open, the tendency in which case is to gradually sink into the roadbed and become mixed with earth.

To meet an important and stated requirement of ballast broken stone should not disintegrate under atmospheric influences or crumble in working. The most suitable rocks for the purpose are trap, granite and limestone. Sandstone is used occasionally, but the ordinary class of material does not make good ballast, as it crushes under the tamping pick and grinds out under the traffic, the tendency being to wear round. The other varieties of rock named break off angularly. Sandstone containing over 95 per cent of silica is said to give satisfactory results. The Norfolk & Western Ry. has in use a quality of sandstone that is very hard and makes first-class ballast. The Seaboard Air Line Ry. is using a quartz ballast, in crystallized form, obtained near Statham, Ga. Among the limestones the hard bastard varieties are preferred to that which will burn into lime, as the latter goes too largely into screenings at the crusher and breaks up considerably in tamping. Magnesian limestone is recommended.

In former years stone ballast was largely hand broken, with napping hammers, sometimes at the quarry but more frequently in or at the side of the track, the unbroken stone being unloaded from the cars in sufficient quantity to supply the required amount of ballast. During recent years such practice has largely been superseded by the use of machine-crushed stone produced in a plant at the quarry and hauled out along the road in ballast cars, like gravel. There is one scheme, however, sometimes employed in ballasting new track, whereby a portable machine with power to operate it and move it slowly forward, crushes the ballast and drops it upon the track. The unbroken rock is first distributed along the track, and then picked up and thrown into the crusher as it moves along.

Crushing Machinery.—Rock Crushers are made in many patterns, but in general there are only two types—jaw crushers and gyratory crushers . In the jaw crusher the rock is broken by being squeezed or pinched between a strong casting and a heavy lever or jaw hinged at the upper end and reciprocated at the lower end by means of a connection with an eccentric on the shaft of a fly wheel. The gyratory crusher consists of a stationary heavy cast shell or casing, with a conical aperture, within which revolves a heavy vertical crushing spindle reversely coned. At its top end this spindle turns in a fixed bearing, but at its bottom end it is journaled into an eccentric, so that, aside from its revolution about its own axis, it is given a gyratory motion, causing it to advance and recede, or wabble, within the stationary casing. To give the machine a biting action on the rock the surface of either the revolving cone or the interior of the casing is fluted or corrugated. The rock is dumped in at the top and is gradually broken up as it settles down between the casing and the wabbling, whirling cone, until it finally passes out at the bottom into a chute. A ballast crushing plant consists of an installation of one or more crushers, with screens for assorting the sizes and means of conveyance for loading the material into the cars. If the crusher can be located some distance above, and near, the track, as at a quarry opened up in the face of a hill, the discharge of ballast into the cars can take place by gravity; otherwise the material usually passes from the crusher into a belt conveyor which elevates it into the screens, whence it slides into the cars through chutes. One arrangement for screening is to have the material slide over a perforated incline, but preferably through a series of revolving screens, or through a single revolving screen with successive sections having perforations of varying size. The cars which receive the various sizes of stone and screenings stand upon parallel tracks under the discharge chutes. The loading tracks should preferably be laid to a grade, so that the cars may be spotted by gravity.

The arrangement of one of the typical rock crushing plants of the Pennsylvania R. R. includes a gyratory crusher having a capacity of 40 to 50 cu. yds. of broken granite rock per hour, with an auxiliary crusher of smaller capacity. The rock is dumped into the large crusher, the discharge from which passes to a belt conveyor and is elevated into a revolving cylindrical steel plate screen 12 ft. long and 4½ ft. in diam. The screen is set at an incline and is divided into three sections, the first and uppermost being closely perforated with 1-in. holes, the second with 2-in. holes and the third with 3-in. holes. Outside the first section there is a concentric wire screen dust jacket of ½-in. mesh, which permits the dust and stones smaller than ½ in. to drop through into a subjacent bin, but carries the ballast from ½ in. to 1 in. in size and drops it into another bin. The second section of the screen drops stones from 1 in. to 2 ins. in size into a third bin; and the third section drops stones from 2 to 3 ins. in size into a fourth bin. The rejected material passes into an extension of the screen at its lower end perforated with slots 6 ins. wide and 12 ins. long, through which it drops into a chute running to the auxiliary crusher, where it is reduced to proper size and again spouted to the conveyor and discharged into the revolving screen. The products which drop into the four bins are of the following proportions: 17 per cent of screenings, from dust to stones of ½ in. size; 8 per cent of stones in sizes from ½ in. to 1 in., commercially known as ¾-in. ballast; 33 per cent of stones in sizes from 1 in. to 2 ins., commercially known as 1½-in. ballast; 42 per cent of stones in sizes of 2 to 3 ins., commercially known as 2½-in. ballast. The four bins discharge through chutes into cars standing upon three parallel tracks, the cars to be loaded with screenings and ¾-in. ballast, respectively, being spotted upon the same track at different times. The grade of the loading tracks is 1 per cent. This plant is operated by an engine of 150 h. p. and the cost of the entire installation was $16,000. The labor required to operate the plant includes one engineer, one fireman, one oiler and four laborers, the wages of all seven men amounting to $1.19½ per hour. The renewal of the principal wearing parts of both crushers costs about $500 for each 400 working hours.

The means for conveying stone from the quarry to the crusher may consist of dump cars, run by gravity or by cable or pulled by horses, or it may consist of an aerial cableway or other power driven conveying machinery. At the plant of the Stewart Contracting Co., Columbia, S. C., ballast contractors for the Southern Ry., the quarry is in a deep pit

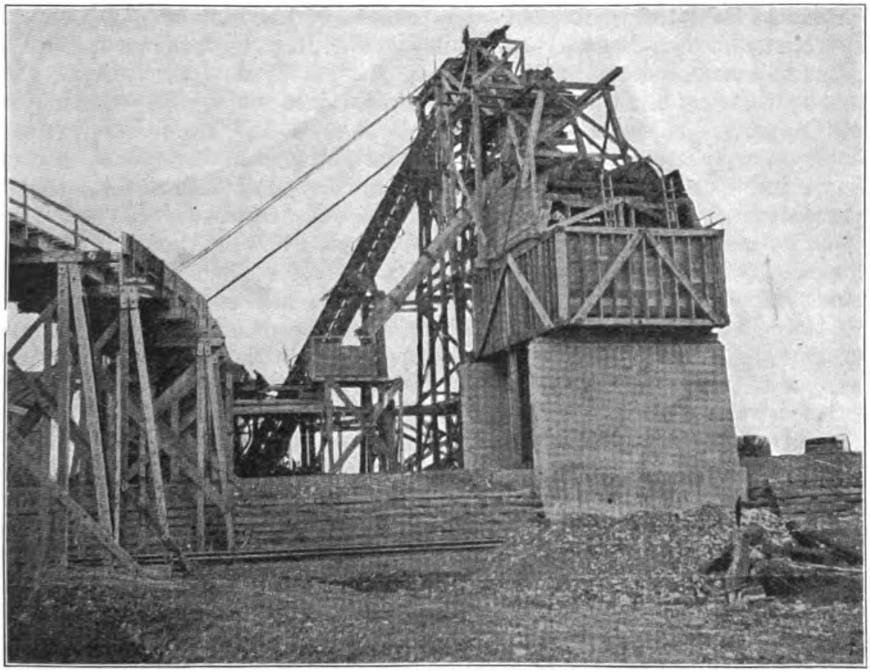


Fig. 30 A.—Ballast Crushing Plant, North Leroy, N. Y., Lehigh Valley R. R.

excavated below the level of the crusher. Rock is fed to the crushing plant in small cars hauled up an incline, and also by means of an "apron" suspended from a trolley running upon a cableway between two towers. At the tower on the opposite end of the cable from the crushing plant there is a hoisting engine which raises the apron out of the quarry after it has been loaded with rock, and then pulls the trolley over the suspended cable to the crusher plant. In 1901 this material (hard granite), broken to 2½ ins., was costing the Southern Ry. 60 cents per cu. yd., on board the cars. At North LeRoy, N. Y., the Duerr Contracting Co. operates a stone crushing plant to supply the Lehigh Valley R. R. with ballast. The stone is quarried and brought to the crushers in tram cars on two tracks, one on each side of the crushing machinery, so that the material may be fed from both sides. As this is one of the largest plants of its kind the general arrangement is interesting. There are three crushing machines with openings 2x6 ft. in each. As the material is dumped from the cars (on the trestle shown at the left in Fig. 30 A) it falls into large hopper bins from which it is fed to the crushers. From the crushers the broken product is delivered to an incline elevator, shown in the center of the view, which conveys it to a hight of 83 ft. and delivers it to a heavy revolving screen. The product from this first screen is delivered to two other screens below, the tailings being returned by a belt conveyor to one of the crushers for recrushing. The product passing from the second screens is delivered into three large bins holding several car-loads. Under the bins are two switching tracks, so that two trains of cars can be loaded at the same time. The elevator and revolving screens are driven by a rope drive. The elevator is of the Common Sense type, with buckets 4 ft. long by 2 ft. wide. The plant is operated by a Corliss engine of 250 h. p., and the capacity is 440 tons of crushed stone per hour.

Some railways operate crushing plants of their own, but it is quite customary to purchase broken stone ballast of contractors, delivered on the cars. An inspector is sometimes detailed for duty at the crushing plant to see that decomposed rock from the top of the quarry is not put in and that the dirt and dust are properly taken out by the screens. In wet weather the screening must usually be watched more closely than during dry weather. In hauling broken stone to a distance it shakes down and there is a considerable shrinkage in volume, amounting to 10 per cent in some cases for a haul of 100 miles. Owing to this fact it is largely the custom to purchase such ballast by weight, the price per ton being determined in relation to the weight of a cubic yard of crushed stone measured in a box freshly filled. In a report to the International Railway Congress, in 1900, Mr. A. Feldpauche, principal assistant engineer of the Philadelphia, Wilmington & Baltimore R. R., put the average weight of a cubic yard of 2½-in. crushed granite at 2450 lbs., and of crushed trap rock of the same size, 2624 lbs.

The cost of broken stone ballast delivered on the track varies widely, according to the expense for quarrying, crushing, hauling and unloading. The cost of putting the ballast under the track and dressing it up also varies considerably, according to the lift of the track, the size of the stone, the price for labor, amount of room available for unloading ballast on the shoulder, etc. For machine crushed stone ballast 45 to 75 cents per cubic yard on board cars, 60 cents to $1.00 per cubic yard delivered on cars, 75 cents per cubic yard unloaded beside the track, 15 to 25 cents per cubic yard for labor of placing under the track and tamping, and 75 cents to $1.25 per cubic yard, in place, in track completely ballasted, lined and dressed, are figures which have been quoted, but not by the same road in every case. During the year 1899 one of the trunk-line railways operating in Ohio purchased from a contractor in that state large but limited quantities of 2-in. crushed limestone ballast for 28 cents per cubic yard, o. b. c., and in 1900 the contract price between the same parties was 33 cents. These extremely low prices were due to the fact that the contractor was stripping quarries to be worked mainly for building stone, and the material disposed of for ballast would otherwise have been wasted. For crushed stone ballast in place, in track completely surfaced, lined and dressed, 85 cents to $1.00 per cubic yard seems to be the average total cost on a number of roads, for a haul not exceeding 200 miles. In 1902 one of the large railway systems running west and northwest from Chicago paid 45 cents per cu. yd. for broken stone ballast, o. b. c. The average cost of putting this ballast under the track, tamping, lining, filling in and dressing off (the track was generally raised 9 ins. and in dressing off but little ballast was placed at the ends of the ties) was 37 cents per cu. yd., train service 10 cents per cu. yd. additional.

The screenings from crushed rock ballast are used in yard and side- tracks and as paving for station platforms, highway crossings and sidewalks.

For stone ballast broken by hand, 10 to 45 cents per cubic yard (no cost for quarrying in the former case) for the unbroken rock placed on the car; 25 to 35 cents per cubic yard for breaking with hammers; 22 to 40 cents per cubic yard for putting it into the track, surfacing, lining and dressing, are figures obtained from official records; also 57½ cents per cubic yard for rock distributed along the road and broken to 2½ ins. in the track, by hand, not figuring the cost of quarrying or hauling; 67 cents per cubic yard for stone unloaded and broken upon the shoulder to a 3-in. ring, counting all costs except hauling, and 30 cents per cubic yard additional for putting it under the track; $1.15 to $1.20 per cubic yard for stone broken on the shoulder and then put into the track, not counting the cost of hauling. On roads where there are rock cuts, the rock being of suitable quality for ballast, it is usually advantageous to quarry the ballast stone in such places; especially if it is broken by hand, as the section men can be employed at such work at odd spells during the winter, and the ballast is convenient for loading. The widening of the cuts is also another consideration of importance, particularly where a second track is in contemplation.

Where broken stone ballast is used to good depth it is sometimes the practice to put in a bottom layer of coarsely broken rock—about the size of cocoanuts, say—for a depth of 6 ins. or so. For soft or wet ground, at least, the use of such stones is not advisable, for the mud will ooze up through the open spaces between the large stones and cause the track to heave in winter. In fact broken stone ballast of ordinary size, placed over soft spots in the roadbed, will settle and gradually become filled with loam or mud which rises through the voids. It is therefore the practice, to some extent, to underlay the ballast in such places with a stratum of cinders or fine gravel or with flat stones, if they can be procured.

Slag.—In regions convenient to blast furnaces slag is cheaply procurable and is much used for ballast. In many or most instances the furnace people are pleased to be able to dispose of it gratis, in order to get it out of the way. Those who have studied the character of the material closely prefer the hard, glassy or vitrified slag that is clear from, or contains but little, free lime; and to secure a uniform product it is coming to be the practice to arrange with the furnace authorities to have the hot material so poured that it will spread out into thin layers. In this way it is rendered hard and brittle and easily broken, whereas if it cools in thick layers the top portion will be vitreous, but the interior and under portions will be porous and difficult to break up. Sometimes this spongy material becomes pulverized in time by the traffic and the repeated action of the track tools, and in cases the dust will cement together again and form a hard layer under the ties that is extremely difficult to work. The properties of slag ballast of good quality are very similar to, or practically the same as, those of broken stone. It is handled in the same manner as broken stone, and in general is perhaps somewhat the cheaper material of the two. It is sometimes broken into large lumps, and thus rendered more easily broken into finer sizes, by throwing cold water upon it while it is cooling from the molten state. It softens, however, when broken in this manner and is not so good, so it is claimed, as when broken in a crusher or by the hammer. At the furnaces it is sometimes broken up by blasting and loaded by steam shovel. Some think that the life of the ties is somewhat shortened by the chemical action of the slag.

One of the roads of the country which makes extensive use of slag ballast is the Southern Ry. The minimum depth under the ties is about 8 ins., except on some of the lines where traffic is light, where 6 ins. is found to be sufficient. In wet cuts it is found to be advantageous to place a layer of cinders on the roadbed before the slag is distributed. The ballast is unloaded from double hopper-bottom cars, the bottom doors being opened just wide enough to allow the slag to come out in quantities required. The cars are hauled slowly over the track, and at the end of the train there is a plow which levels the material off even with top of rail. On this road an average day's work in surfacing track with slag ballast, placing it in good surface and line and dressing off, is 17 ft. per man. The slag is loaded with steam shovels at a cost of 5 to 5½ cents per cubic yard. The material weighs 2700 lbs. per cubic yard and about 24 cu. yds. are loaded upon each car. In order to handle the material with steam shovel, it is necessary to blast it. The material is found to be cheaper than broken stone but is not considered quite so good, although it can be worked somewhat more rapidly. It pulverizes under the tamping pick to some extent, and on account of the acid contained in the material the life of the ties is not as long as in broken-stone ballast.

Gravel.—Gravel is found in large deposits widely distributed and is the universal ballast material. All things considered, gravel of good quality is probably the most efficient material for ballast. As compared with broken stone it is inferior in but few respects, while in some ways it is superior. Its area of support is not so diverging as that of broken stone; still it is firm, and when used in sufficient depth it holds track to surface satisfactorily. Where it can be obtained in desirable quantities the ease with which it can be handled in loading and in working makes it the cheapest of all materials for ballast which are of unlimited supply. It seems to be the opinion of the largest number of track maintenance officials, including those having experience with broken stone, that track in good gravel ballast can be put into first-class condition and be maintained in that condition at less cost than in any other ballast. It offers good drainage for water and, if of fair quality, is not heaved by frost. As a mass it is more elastic than broken stone, is easier on ties and rolling stock and is not so noisy under train operation. It is easily handled in tie renewals, frequently without the use of the pick, and is easily worked in tamping. Weeds and grass do not grow readily in clean gravel (free from loam), and such vegetation as does get started when the gravel becomes dirty is more easily subdued than is the case with such growth in broken stone and some other kinds of ballast.

Fine gravel, or that which will all drop through a sieve of 1½-in. mesh, is considered the best, although a few prefer a coarser size. Gravel much coarser than this may give good satisfaction providing a sufficient quantity of sand or finer gravel is mixed with it to fill the voids or interstices. The proportion of sand and small pebbles contained in the gravel determines very largely its worth for ballast. Thirty to 45 per cent of sand (preferably coarse, sharp sand) is considered about the right proportion. Gravel containing more than 50 per cent of sand is considered dusty and inferior in holding qualities as the proportion of sand grows larger. Material containing as much as 75 or 80 per cent of sand would probably be classed as sand, for ballast purposes. The qualities of gravel ballast in relation to the proportion of sand might be expected to depend a great deal upon the character of the sand. Gravel containing a given percentage of coarse sand might be better material to hold track than another grade containing a smaller percentage of fine sand. The distinction between coarse sand and fine gravel, in this connection, might be drawn at such material as is used for sand in ordinary building purposes, like masonry work.

A considerable quantity of soil or loam mixed with gravel helps the growth of weeds and grass and makes the ballast soft when it gets wet. For this reason the soil which overlies a gravel bank should be stripped off in advance of the loading of the cars, for although the amount of soil mixed with the gravel may be comparatively small, yet it takes but a little earthy material to fertilize the gravel sufficiently to enable vegetation to take root. The stripping of gravel pits is usually done with teams and scrapers. In case it is desired to replace the soil after the pit has been worked out the soil is usually scraped into long heaps at a distance apart which corresponds to the width of a cut with the steam shovel. Each time the shovel makes a cut through the bank the soil lying along the brink is thrown down and spread over the bottom of the pit.

Screened gravel ballast is being tried on American railways to some extent. On the Pennsylvania Lines West, where such material is being used in an experimental way the screening is done in a machine consisting essentially of an elevator and a revolving screen, which deposits the sand and clean ballast in separate cars. The cost is intermediate between that of broken stone and gravel. The length of time during which screened gravel has been on trial has been too short to ascertain its value decisively, but experience on the Grand Trunk Ry. with beach gravel washed almost free from sand is officially reported to have been disappointing. The track is free from dust and vegetation, but the ballast does not seem to bond well, and it does not hold the track in line and surface as well as does ordinary gravel. "Washed" gravel is a term applied to material washed by both natural and artificial means. The former is usually obtained from creek or river beds and is used in limited quantities on a number of railways in this country, one of which is the Kansas City, Pittsburg & Gulf R. R. (Kansas City Southern system). Several of the railways of France wash gravel ballast artificially, to remove loam or clay, and sometimes to remove part or all of the sand where no earthy material or clay is contained. A typical washing machine consists essentially of a steel cylinder or barrel about 20 ft. long and 3 ft. in diam., perforated with holes $\frac{3}{8}$ to $\frac{5}{8}$ in. diam., to permit the egress of water, mud and other fine particles. The cylinder is inclined to the horizontal and within it there is a revolving shaft armed with steel blades helically arranged. The supply of water enters through passageways attached to the revolving shaft. The material to be washed enters the cylinder at the lower end and is driven by the blades toward the upper end, where the clean stones fall into a chute which conveys them to the ballast cars. The muddy water and small debris drop into troughs underneath the washing cylinder and are conveyed away. The operation is quite similar to that of some of the iron ore washing plants in central Pennsylvania. In differently constructed plants the material to be washed is run over a riddle or through a revolving screen with a copious intermixture of water. If it is desired to retain a portion of the sand or small gravel a screen is used which has a smaller number of openings, so that it cannot pass the finer material freely.

One of the most undesirable properties, peculiar to gravel in some locations, is a cementing action due to the infiltration of calcareous material or iron oxides. Such material is known among railroad men as "cementing" gravel, and is usually avoided, even at the expense of hauling freely mixed material a long distance. Cementing gravel is as difficult to work as is broken stone ballast, and sometimes even more so, the work of removing it from the track reminding one very much of picking frost. Gravels containing a large proportion of flat or angular-edged stones, formed principally by disintegration, are the worst to contend with, for in such material the vibration set up by the traffic and the settling action of rains causes the mass to become compacted by the overlapping and dovetailing of the parts, independently of any chemical action due to infiltration. Similar results are also promoted by the presence of angular sands. A remedy which has been suggested for such material, in cases where it forms the chief available ballast, is to prevent the mechanical process by mixing with it water-worn or loose material in the proportion of $\frac{1}{4}$ to $\frac{1}{3}$ of the entire mass. By unloading both kinds of ballast at the sides of the track the mixing can be done roughly as the material is shoveled into the track, without extra expense for handling. A desirable way of utilizing cementing gravel, where some proportion of better gravel can be obtained, would be to raise the track and tamp it to surface with the inferior material and then level the ballast down even with the bottoms of the ties and fill in the track and dress it off with the material of the better class.

The cost of gravel ballast in place in completed track varies between wide limits, owing to the diversity of conditions attending the loading, hauling and unloading of the material and the hight to which the track is raised when ballasted. Limits of cost commonly met with are 15 to 40 cents per cubic yard, with figures between 20 and 30 cents per cubic yard occurring most frequently. In one instance the official records of a season's work show that fine gravel ballast was placed in the track at a total cost of 23 cents per cubic yard, including the loading (by hand), the hauling out and placing under the track, which was raised an average of 6 ins.; tamping was done with shovels. In these costs 10 to 15 cents per cubic yard is the usual proportion of expense due to handling the gravel after it is delivered on or at the side of the track, which includes the labor of placing it under the track, shovel tamping, filling in and dressing off.

Combination Ballast.—As broken stone ballast is conceded all the desirable properties respecting stability and drainage, and as gravel is usually cheaper in first cost and in cost of working, it is considered good practice to combine the two, using broken or crushed stone for a foundation, with gravel above it for tamping immediately under the ties and for the filling material. One method that can be followed when ballasting new track is to lift the track about 6 ins., ballast it with broken stone and then wait for the roadbed to settle. The track may then be raised $1\frac{1}{2}$ or 2 ins. and ballasted and filled in with gravel. Where this method is contemplated, at the first ballasting the track need not be filled in full or dressed off; in case it should be, however, the ridges between the ties should be leveled down at the second ballasting. A perhaps better method for new roads is to ballast the track with broken stone and immediately level the material even with the bottoms of the ties and fill in with gravel. As the track settles out of surface owing to roadbed shrinkage it will be raised and tamped with the gravel, and in time will have the desired depth of gravel for support. Sometimes, to economize in cost, the reverse process is carried out; that is, gravel or cinders is used at first, and after the roadbed settles and becomes compacted the track is raised about 6 ins. and rock ballasted. The former method seems the better, since, for ease of working, it is desirable to have loose material for filling.

The plan of using broken stone or equivalent ballast for bearing and some easier working material, like gravel or locomotive cinders, for filling between the ties has been practiced to a considerable extent. The use of broken stone above the bottoms of the ties in preference to gravel is of no advantage except as it prevents dust from rising. The Chicago, Rock Island & Pacific Ry. has used cinder filling on broken stone ballast quite a good deal, particularly where the stone has been of an inferior quality, and good results have been obtained. At one time the Lehigh Valley R. R. ballasted main second track at various places and the "Mountain Cut-off Line," near Wilkes Barre, Pa., with a foundation of broken slag topped out with anthracite engine cinders in a light layer under the ties and for filling between them. Experience showed that the cost of track work was much reduced (compared with work in stone ballast) and the results were generally good. On the Chicago, Milwaukee & St. Paul Ry. the use of sandy gravel on top of coarsely broken rock ballast did not give satisfaction. The broken-stone ballast had been in service for some years and had settled to a firm bed, when the track was raised about 2 ins., the stone filling between the ties was leveled out on the shoulder, and the track was then carefully surfaced with gravel and filled in with the same material. After a little time the section men began to complain that the track was not holding well to surface, and after five years of this experience it was concluded that the combination had not worked satisfactorily. The gravel contained more than the usual proportion of sand for ballast of first quality, but still it was what might be considered fairly good material for ballast. The broken stone was slightly above medium size. The principal difficulty arose from the working of the stone up through the gravel, somewhat as clay is liable to do in a wet cut. It seems that through the jarring of the traffic the sandy part of the gravel settled down through the stone, and that nowhere between the surface of the filling material and the original roadbed could a line be drawn between the gravel and the stone. The two kinds of material had become quite generally mixed together. On the Kansas City line of this road burnt clay ballast has been used on worn-out stone ballast with splendid results.

Cinders.—Cinders makes splendid ballast, and is too frequently consigned to side-tracks or used for filling up hollows and old excavations near the roundhouse when ballast of inferior material is used in main track. Cinders should always be saved for ballast. Under the subject of "Ash Pits" (§ 178, Chap. XI.) several arrangements are considered for cheaply handling and loading into cars the cinders dumped at roundhouses. Even when loaded by hand cinders is very cheap material for ballast, for it is easily handled in scoop shovels. By good rights the cost of loading cinders and laying it down at the side of the track should not be chargeable to the ballast account at all, for it is a waste product, and the ash dumps at the terminals must be loaded into cars and hauled off at more or less frequent intervals, in any case, in order to get them out of the way. On such considerations cinders is a very economical ballast, so far as it goes, furnishing, in fact, the cheapest material available for ballast renewals; and in a convenient manner, for the loaded cars may be shipped daily by local freight trains to points where ballast is needed or else allowed to accumulate for a few days at a time to be handled in the work train. The dumpings from locomotives contain very little ash proper, since the ash, for the most part, goes out through the smoke stack with the exhaust, leaving behind cinders, clinkers or slag, burned rock, slate etc. Cinder soon slakes, like lime, and makes a uniformly compact mass well adapted for ballast. The remarkable feature about coal cinder is its capacity for absorbing water. A heavy rain can be taken up and held within two inches of the top surface of a pile of cinders. In track ballasted with cinders comparatively little water reaches as far as the bottom of the tie, but is held near the surface until evaporated; and evaporation takes place quickly when the material is exposed to the sun. Except when the rains are prolonged this ballast keeps the roadbed in better condition than does either rock or gravel ballast. It is fine material to handle and is proof against weeds; it keeps track in even surface and does not heave in winter more than a slight bulging on the top surface. Like broken stone its area of support diverges rapidly with depth, and for use on wet or soft roadbeds it is the best material that can be obtained.

The principal objections against cinder ballast for main track are the dust, in dry weather, and the fact that it wears away more rapidly than gravel or broken rock. It is also generally conceded that the life of ties is slightly shorter in cinder than in stone or gravel ballast. This fact is usually attributed to the action of the sulphur in the cinders, which is supposed to be most pronounced during the occurrence of light rains. Locomotive engineers complain that at such times a lubricant is formed on the rails where the track is cinder ballasted, which greatly impairs the adhesion of the drivers, but whether such lubricant is due to moistened cinder dust on the rail or to the chemical effect on the brightened rail top of gases set free by the action of the water on the cinders, has not been well established. At any rate cinders is not considered good ballast material for heavy grades. Notwithstanding these drawbacks, however, the value of cinders for ballast is not to be lightly considered.

Sand Ballast.—Sand is inferior to either gravel or cinders, for ballast, but is much used, for the simple reason that it is widely distributed, and over extended districts it is the best material available. As a matter of fact gravel easily grades off into sand, and much of so-called gravel ballast is sand with stones or pebbles few and far between, so that it is practically sand ballast. It is retentive of water to some extent and, while it does not usually become plastic when wet, it is heaved by freezing. It cannot be worked when very wet, and it cannot be worked to best advantage when very dry. It is easily handled, and while weeds will grow in sand of ordinary quality they can usually be kept down without difficulty. Where the drainage is good and rains are infrequent it holds track to surface quite well. In southern California, Arizona and parts of Mexico, where the climate is generally dry, adobe sand is much used for ballast, and with fair satisfaction.

Sand ballast is of fugitive character, being, like old cinder ballast, considerably wasted in dry weather by winds and by breezes stirred up by fast trains. In dry weather the dust from fast trains running over sand ballast is a "fright." It is injurious to rolling stock, causes trouble from hot boxes and makes uncomfortable traveling, which passengers will avoid, if they can do so, by taking another route the next trip. In France, Russia and India it is quite commonly the practice, where fine sand ballast is used, to cover the roadbed and track filling with a layer of broken stone or gravel, to keep down the dust and prevent the sand from blowing away. The same plan is followed on the Mexican Southern Ry. When repairs require the removal of the ballast the broken stone is first raked off into a pile and kept separate from the sand. In France small brick tiles, manufactured for the purpose, are sometimes used in lieu of broken stone for covering up sand ballast.

As a measure for keeping down the dust on some of the sand-ballasted railways of the South, Bermuda grass is permitted to grow over the track. This grass does not generally grow higher than the rails and consequently does not interfere with locomotive traction. It grows in the form of a mat and springs up rapidly after the sod has been disturbed in the renewal of ties. Sand which is entirely free from loam will not support this grass. The Louisville & Nashville R. R. has had satisfactory experience with it, for the purpose here stated, on some of its sandy divisions, but on the Pensacola & Atlantic division the effort to cultivate the grass was not successful, owing to the infertility of the sand. It is used in the southern states all the way from the Atlantic coast to points in Texas, and is found very effectual in preventing soft banks from washing. As elsewhere stated, it is set out in squares on embankments, and eventually covers the whole ground surface. It is a jointed grass, the joints being a few inches apart, and as it creeps along it puts down new roots at each joint. Under favorable conditions the roots penetrate the earth 3 to 5 ft. and form a compact mass. It is then next to impossible to eradicate it. A blade of the grass dropped on the ground will take root and grow. When it gets into the track it is a waste of time to try to cut it out. In Florida, where it grows larger than in the states farther north, it stands 4 to 6 ins. high, but ordinarily the blades are only about 3 ins. long, and it does not interfere materially with track work. Except during long periods of drouth it is green the year round. On the east coast of Florida it is called "St. Lucie" grass, although the botanists claim there is a slight distinction.

Dirt.—If there is anything that will depress the spirits of an old trackman who has been accustomed to rock or gravel ballast it is a change to track ballasted with dirt, often called "mud" ballast (and very appropriately, too, during certain seasons of the year). Still, where it must be done, track can be kept up in dirt ballast, for a very large mileage of track in this country is dirt ballasted. Dirt or mud ballast is the common earth, of almost any kind at hand, usually thrown up from within reach of the track. It can often be improved by casting aside the top layer of the ground, or the soil which would grow weeds most readily, and using only the subsoil. Earth varies so much that it is difficult to classify the varieties of dirt ballast, but it gets better the more sand it contains. Argillaceous earth bakes hard in dry, hot weather and at such times it is difficult to work. Generally speaking, it may be said that it is the very opposite of broken stone or gravel, so far as answering the requirements of a good ballast, for it answers none well. It settles easily under load and, if drainage be defective, becomes literally a mud puddle in wet weather. It heaves badly during freezing weather and usually grows grass and weeds as abundantly as a garden, in summer. It goes without saying that it should not be used in any place where it is feasible to get better ballast. On some roads carrying light traffic there may be circumstances which make its use expedient, if not economical. It is always cheaply procured and is easily handled, which compensate in some degree for the labor expense of keeping it up. Good drainage makes dirt ballast a possibility, and good judgment and experience teach methods of work which render its use practicable. Happy ought to be the foremen who have never had occasion to know anything about it!

Burnt Clay.—In the Mississippi Valley a "patent" (but not patented) ballast is manufactured extensively by depositing gumbo or clay and coal slack in layers and burning the two together. The product is a dry material bearing a close resemblance to broken brick. It makes good ballast, can be handled and worked as easily as gravel, and costs less than broken stone. It has a marked affinity for water, surpassing any other ballast in this respect, absorbing ordinary rainfall and keeping the roadbed dry. When well burned it does not return to the original condition of the clay. It does not grow weeds readily, being similar to cinders in this respect. The manner of its preparation is something like the following: A side-track is laid over the ground where the material is found and, parallel to this track at a convenient distance for loading, old ties or cord wood are placed in a long pile about 4 ft. wide and 3 ft. high. Coal slack is sprinkled through the wood and the pile is covered over with a layer of clay about 12 ins. deep. To give draft while burning the first layer of fuel and clay, or while the kiln is being heated up, an open space is sometimes formed underneath the fuel, in the bed of the kiln, by throwing up two ridges of earth with material excavated from a shallow trench between them, and the wood is piled crosswise these ridges. After setting fire to the ends and at intervals the heap is closed and alternate layers of coal slack, 6 to 8 ins. thick, and clay, 12 ins. thick, are added as the heap burns down. The heap keeps sinking and burning away and, when finally burned, the pile may be something like 10 ft. in hight and 20 ft. wide.

It is said that the best quality of ballast is produced from tough "gumbo" or "black wax" clay, which is fatter material than would be used in burning brick. The presence of sand, which is desirable in brick clay, is detrimental to the material for the purposes of ballast. The clay should be burned hard, even to vitrification, as it is easily broken up. In dry weather one ton of slack will burn from 4 to 5 cu. yds. of ballast. The cost ranges from 25 cents per cubic yard upward, for the finished product in the pile, depending upon the price of labor and fuel, the depth at which the layer of suitable material is found, cost of laying side-track to the pit, the amount of stripping in order to get at the raw material, the draining of the pits, etc. The burning of clay ballast is frequently undertaken on a large scale, the kiln being ½ to 1 mile in length. On work of this magnitude the clay is usually excavated and placed upon the kiln by some machine of the steam shovel or belt conveyor type, running on a track on the opposite side of the kiln from the loading track. The ballast material is excavated from a trench between this track and the kiln, the trench being sometimes dug to the depth of 8 ft. It is desirable that the material to be burned should be excavated in lumps and placed upon the fire without being much broken up. The burned clay may be loaded by steam shovel or by hand, throwing the track in to the heap as it becomes shoveled away. It is customary to let the forming and burning of the kiln out to experienced contractors, who furnish the machinery and the labor, while the railway company supplies the land, the tracks and the fuel, the last named purposely to insure that a sufficient quantity will be used to properly burn the clay. Contract prices for handling the clay and burning the kiln have been made as low as 19 cents (and perhaps lower) per cubic yard of ballast, the railway company supplying the fuel. The usual prices in the vicinity of the Missouri river range from 20 to 25 cents per cu. yd. Coal slack or refuse, for burning, is sometimes bought as low as 25 cents per ton, at the mine. Almost any quality of coal may be used, but the quality of the ballast is said to improve with the quality of the coal used in burning it. In some cases a small percentage of nut coal, with a considerable quantity of mixed coal, has been mixed with the slack. In wet weather a little run-of-mine coal is sometimes used to bring the fire up. In the experience of the Chicago, Milwaukee & St. Paul Ry. the use of an excess quantity of coal in the burning of clay ballast is detrimental to the properties of the material. The large proportion of ash resulting from too much fuel causes the ballast to soften when it becomes wet.

When first put into the track this ballast is very dusty, owing to the ashes intermixed, but after a good rain it becomes clean and remains in that condition. The material is light, weighing only 1500 to 1700 lbs. per cu. yd., according to the character of the raw material and the thoroughness in burning. In some records it is found as heavy as 1800 lbs. per cu. yd., and as a rule the poorly burned ballast is heavier than that which is well burned. It is said that burned clay ballast of good quality does not wear out faster than gravel or stone, although in time it becomes somewhat finely broken up and settles down. So long as this ballast does not become mixed with foreign material it will not grow weeds, but dust blown upon it from plowed fields will in time so contaminate it that it will support vegetation. On the Chicago, Burlington & Quincy, the Atchison, Topeka & Santa Fe, the Chicago, Milwaukee & St. Paul, the Wabash and other western roads it is in extensive service. The first that was used in this country was burned in Iowa, in 1880, for the Chicago, Burlington & Quincy Ry.

Mr. W. Shea, roadmaster on the Kansas City line of the Chicago, Milwaukee & St. Paul Ry., speaking from an experience of 12 years with both burnt clay and broken stone ballast, has made the following comparison: "For ordinary traffic I prefer burnt clay ballast to rock ballast, as I consider that track can be maintained in better condition for less money with the clay ballast than with the rock, and the life of the burnt clay ballast seems to be about as long as the rock. Weeds can be cleaned out of the burnt clay ballast for one-quarter the cost that they can out of rock. Ties can be renewed in burnt clay ballast for forty per cent less than in rock ballast. The life of a tie in burned clay ballast is ten per cent longer than in rock. I account for this on the ground that the clay is porous and dries out quicker, so that it draws the dampness out of the tie, not waiting for the common elements to dry the tie out after being wet. We dress and shoulder our track in burnt clay ballast the same as in good gravel ballast."

Miscellaneous Ballast.—The foregoing kinds of ballast are in common use, and, except in the case of burnt clay (which, however, is in use over a large extent of territory), each is found in many and widely separated parts of the country. Nevertheless the expense of transportation is so large a factor in the procurement of suitable ballast at economical cost, that local conditions of supply assume importance as the source of supply of a desirable ballast becomes farther removed. The result is a considerable list of miscellaneous ballast materials, both natural and artificial, used in practice, each being identified more or less distinctively with some particular locality. Mention will be made of the best known of these materials. In eastern Pennsylvania anthracite coal dust or culm from the breakers is used to some extent on several roads in the vicinity of the mining regions. It is a mobile substance, and for the best results must be confined at the sides of the roadbed. It is particularly serviceable on wet roadbed, as it is not softened by water and does not heave by freezing. So long as it remains unmixed with foreign material it does not harden or become compact and make a firm support, but it settles evenly when of uniform depth.

It is very easily worked—in fact, too easily, being too untenacious for bar tamping. It does not grow vegetation.

Decomposed rock is used for ballast on several roads in the West and South. On the Southern Pacific and Union Pacific roads the material of this description is decomposed granite, which makes pretty good ballast; in fact, that used on the Union Pacific R. R. is first class. This material is from Sherman hill, the summit of the road. It is a disintegrated mica granite and the aggregation of the material is similar to that of a fine quality of gravel. It is gritty, does not grow weeds, and is dustless. It is used to a depth of 9 ins. under the ties. From the pits near Sherman this material has been excavated for ballasting the road all the way from Council Bluffs, Ia., to Green River, Wyo., a distance of 827 miles. The haul from Sherman to Council Bluffs is 550 miles. It is loaded with steam shovels, much of it being excavated without blasting, but, generally speaking, more economical results are obtained by the use of some powder. Under favorable conditions this material has been excavated and loaded for about 6 cts. per cu. yd., which included all the expenses in the pit. Decomposed shale is used on some roads, to small extent, but is not as good as decomposed granite. It becomes very compact and firm and hard to work, when dry, but churns into mud during long spells of wet weather.

Another material used on a few railroads is "chatts," or the tailings from lead and zinc mills. It is the residue from quartz rock after the ore has been separated by crushing, and is in grains about the size of kernels of wheat. It is heavy material, easy to work and free from dust. On the St. Louis & San Francisco it is used extensively for ballast.

On its lines in Arizona the Atchison, Topeka & Santa Fe Ry. uses large quantities of volcanic cinder for ballast. It is excavated from pits with steam shovels and in character bears a close resemblance to burnt clay ballast. In ballasting track it is first tamped with shovels, surfacing up later with tamping bars. At various points on the Kansas City branch of the Chicago, Milwaukee & St. Paul Ry. extensive use is being made of burnt shale, or mine cinder, for ballast. This material in its original condition consists of shaly rock or slate, being refuse from soft coal mines, and is piled up in large heaps to get it out of the way. It takes fire spontaneously, and, with the considerable amount of coal unavoidably mixed with it, burns down to a material possessing some of the properties of burnt clay ballast, but is unlike it in several respects. In places where too much coal has become intermixed with the shale the large quantity of ash has a deteriorating effect on the ballast, causing it to take on a muddy consistency when it becomes wet. This material is giving good satisfaction as ballast.

In the Chesapeake bay region a considerable mileage of track is ballasted with oyster shells, costing about 21 cents per cu. yd. on the cars. The material is dustless, but too light for the best results, and the admixture of animal matter with accumulated dust encourages the growth of vegetation.

CHAPTER III.

TRACK-LAYING.

13.—Track-laying, in American countries, signifies the placing of the ties, rails and fastenings and the spiking of the rails. It includes only such temporary work in lining and surfacing as is necessary to enable the track to carry the construction train safely, and without permanently bending or kinking the rails. To meet this requirement the alignment of the track need conform only approximately to that of the center stakes; quite frequently the alignment as it is left by the spikers is sufficient for this temporary purpose. As to the surface requirements, there should be no abrupt humps or short sags, causing several ties in succession to be suspended from the rails without support from the roadbed. The work of placing track in smooth surface and alignment is a part of the operation of ballasting. In cases where the ballasting is to be delayed for some time after the operation of the road is begun the track is usually surfaced with earth to temporarily carry the traffic.

The fact that the necessities of construction do not require completed work in line and surface apparently conveys to some railroad men inexperienced with track maintenance an impression that the workmanship of track-laying is necessarily crude; hence it has become quite customary to sacrifice skillful work for speed in construction. In typical cases of railway building it has seemed that both the officials of the road and the contractors have regarded track-laying a good deal as a large class of farmers do the season of haying and harvesting—a time for rushing all work through at utmost speed, by an outlay of human strength to the utmost limit of physical endurance, and by working from daylight to dark every day until the job is finished. The scheme of building a railroad is often decided upon suddenly, and, with some object or other in view, usually to accommodate a rush of settlers, to hasten the time of earning dividends on the investment, or to head off a rival project, the circumstances seem to require the greatest possible speed in construction. In building new roads it has frequently happened that engineers have been so crowded for time that they have been unable to give proper attention to location, earthwork, etc.; still in no part of the work of railway building do men sometimes get so wild as in track-laying. Patience is lost as soon as the wheels of the construction train begin to turn. A time limit—or what amounts to the same thing, a minimum length of track to be laid per day—with a contractor seems to justify him in his belief that almost any measures or methods which can operate to his advantage in pushing things forward will be overlooked by the railway company, so long as he fulfills the all-important requirement of speed. Consequently the really most important matters connected with track-laying are too often left to the men the least interested—the laborers; and when it comes to pushing a disinterested party beyond reason it is not to be expected that he will very much care how he does his work. Speed in construction is sometimes a subject of much boasting, but less frequently considered in its bearing upon maintenance work. Unless some great interest or issue be at stake anything gained in speed by laying track in the careless manner so prevalent in the past is soon lost many times over in the poor track and early repairs which must stand as the result of the undue haste. In order to accomplish the best results in track maintenance, from the start, the work of track-laying must be done carefully and in a substantial manner. It requires the exercise of good judgment, under the conditions at hand, and no part of the work should be left uncompleted. In ordinary cases the question of speed in construction should be deemed of secondary importance. A continual cry for haste invites every man concerned to slight some part of the work. Now that track-laying is being done more largely by the railroad companies and less by contractors than formerly, there is less excuse for that sort of thing.

Center Stakes.—For the purposes of track-laying it is not necessary to set center stakes closer than 100 ft. apart on tangents and 50 ft. apart on simple curves. The practice of setting center stakes 50 ft. apart on tangents is useless and makes unnecessary expense. In order to stand firmly center stakes should be of good size, say about 2x2x18 ins., for ordinary ground in its natural state, and 6 ins. longer for made ground, such as embankments, and for soft roadbed. The stakes should be of tough wood, like oak or hard pine, and sawed stakes are the most convenient to handle. One of the reasons for this brief reference to the subject of center stakes is the fact that small stakes of soft wood are sometimes used, and with evidently poor satisfaction, not penetrating the ground far enough to stand firmly, or else being so soft that the stake splits and breaks up in driving. In order that the stakes may remain for service when the track is being ballasted they must be driven firmly enough to withstand slight knocks, such, for instance, as when stubbed against by the toe of a boot. A number of disturbing causes may be avoided by driving the stake to a good depth, so that it stands not more than 3 or 4 ins. out of the ground.

14. Outfit Train.—Where there is much track to lay the first thing to get ready is the outfit train. It should consist essentially of bunk or sleeping cars, kitchen car and dining cars, for the men; a tool car, a supply and office car, a locomotive, car-load of fuel; a water tank car, if needed; and a caboose for the train crew. Where the grades are not steep the best arrangement is to put the dining, kitchen, bunk and office cars to the front, as then they do not have to be handled by the locomotive in running back after material; it also gives the cooks better opportunity to do their work, and the dining cars are always on hand at meal time. The office and bunk cars should be ahead, followed by the dining car, with the kitchen car coupled in next behind. If there are two dining cars the kitchen car should be between them. Next behind may come the tool car, which is usually a flat car with large boxes, but sometimes a box car. On this car may also be placed some water barrels, fuel, etc., for the cooks. There should be end doors in all the cars, so that one may walk through the train from end to end. Next behind come the cars loaded with rails, then the car carrying spikes, bolts and splices, and after that the cars loaded with ties. Behind the ties should be put the fuel car, if carried, and behind this the locomotive, turned backwards to the direction in which the work is progressing. It should be provided with sand pipes which can be used when running in either direction. In any case the fuel should be next the tender, and the water car next to it, if used, and provided with a piece of hose long enough to reach the tender around the fuel car. Where streams are plentiful along the route the water car may be dispensed with by providing a steam siphon for the locomotive. The locomotive should be the heaviest one available, especially if track is to be laid on mountain grades. On work of considerable magnitude it usually pays to have a blacksmith, with a car carrying a portable set of tools, accompany the outfit train, and if the contractors do a mercantile business with their employees there are store cars also, carrying supplies of workmen's clothing, provisions, tobacco, etc.

In laying track up heavy grades or through a broken country where the construction of bridges interferes with the track-laying, it is impracticable to keep the outfit cars at the front. In such cases they are side-tracked a few days at a time at convenient points as the work progresses. This is easily and quickly done by disconnecting the track and throwing it over to a temporarily built piece of track or spur and afterward throwing it back to main line, thereby leaving the cars standing on the isolated piece of track. When it becomes necessary to move the outfit ahead again the main track is disconnected and thrown over as before, the cars hauled off, track thrown back to place, and the temporary piece taken up, all in a very short time. On level track or easy grades an ordinary locomotive can handle the outfit cars besides the material for a mile of track, in one load. Material for a mile of track includes about eight ordinary car-loads of ties, five car-loads of rails and a car-load of fastenings. Where possible, a whole day's supply of material should be carried in one train load, except perhaps when close to the base of supplies.

On roads where the track-laying lasts but a season or two the outfit cars usually consist of box cars temporarily converted for the various uses, but for longer service or for the service of contractors it is usual to make use of specially built double-deck cars. An ordinary arrangement is to have cars with a dining room on first floor and sleeping quarters overhead. The office and supply car, or store car, usually has a sleeping apartment on second floor. Such specially built cars usually have a cellar or box suspended underneath for carrying the tools. The water car is sometimes an ordinary oil-tank car and sometimes it is a flat car having a wooden tank over each truck, with a pipe connection between the tanks. A more detailed description of the construction and arrangement of boarding cars is given in § 143, Chap. X. The health of the crew requires that attention be paid to cleanliness around the kitchen and dining cars, and for both health and comfort the sleeping cars should be thoroughly renovated occasionally. A sleeping car is easily and effectively cleared of bedbugs and like inhabitants by putting it on a side-track and, after closing it tightly, turning live steam into it by hose from the locomotive until the pressure is as great as the body of the car can stand. After this the old bunk straw should be thrown out and the car thoroughly scrubbed.

15. Material Yard and Side-Tracks.—In starting out to lay track for any considerable distance it is necessary, in order to keep the work going continuously, to lay in a good-sized stock of material at some point conveniently situated for forwarding to the front. To provide room for the accumulation of this material and facilities for expeditiously handling the same there should be a systematically arranged yard, even if such must be built for only temporary use. All the material for the front is then shipped through this yard. Of course, after track-laying has begun, shipments of material received are forwarded direct to the front, as far as it is practicable to do so, without unloading or transferring at the yard; but such transferring as must be done, as, for instance, the changing of rails from box to flat cars, is done in the material yard. The material yard is then the storehouse where the reserve stock is kept on hand and the point where the supply of material for the front is regulated. In building a long line the material yard must be moved forward, from time to time, being usually kept within a day's run of the front. In building long lines the laying out of the material yard in such a manner that the material can be unloaded properly and reloaded quickly and cheaply is a very important matter. The delaying of the track-laying force for an hour now and then costs a good deal in the end. For information on material yards in further detail the reader is referred to §198, Supplementary Notes, by Mr. John Smith, a railroad contractor of long experience.

In order to keep supplies of material within convenient distance of the construction train it is usual to lay side-tracks from time to time as the work advances. On new lines in the West these side-tracks are usually put in about 10 miles apart, seldom farther, and sometimes as close as six or eight miles, the aim frequently being to select such points as seem likely to become future stations or town sites. The ordinary length of such side-tracks is about ½ mile, and in event the supply of material is short, or if there is no prospect that the side-track will remain permanently, it is usually only half tied, half bolted, etc. At such sidings the construction train exchanges its empty cars for loaded ones brought thither from the material yard by the "swing train," as it is commonly known. According to the usual custom in track-laying on long lines the swing train brings the material up to the farthest side-track in trains made up in proper order for the front, so that the train which handles the material at the end of the track need not run farther back than the first side-track in the rear, and no switching of the cars is necessary. Such sidings as are to remain permanently, for passing tracks or other purposes, should be built double ended, or with a switch at both ends, as then if the engine of the construction train is able to push a whole day's supply to the front it can leave its empties on main track, run in at the rear of the siding and push the loaded cars straight ahead to the front; while the engine of the swing train as it approaches the siding may first push the empties beyond the siding and then enter it with the loaded cars, cut loose, run out on to main track and return with the empties—all without switching the trains. It is usually the case, however, that the front end of the side-track is occupied by the boarding train, cars loaded with bridge timbers, etc. In such event the engine of the "swing" train is usually run around to the rear of the train at the next to the last side-track, pushing the train from that point to the last side-track.

The proper time to lay side-tracks is as soon as the desired points are reached, and not to first go by them two or three miles. If the boarding outfit is kept in the side-tracks, the sooner each side-track is built the sooner can the boarding train be moved up so as to get the benefit of the short run from camp to the end of the track, in taking the men to and from the work. It is the usual, in fact nearly the universal, custom to take out a half day's supply of material to the end of the track in the morning and return for dinner, and then take back the material for the afternoon's work. If the speed of track-laying is only a mile or 1¼ miles per day the supply or swing train can, if the grades are not steep, take out the whole day's supply in a single trip.

As in most parts of the West it is necessary to take out water cars to supply the locomotive of the construction train and the boarding camp, it is seldom that material for more than the length of track named is hauled in a single trip, and usually the side-tracks will not hold much more, with the boarding train, bridge material cars, etc. When track is laid at the rate of two miles per day or faster it is usually necessary for the supply train to make two trips between the material yard and the farthest side-track, bringing a half day's supply at a time. It should be timed to get out to the siding as early as 11:30 a. m. and again in the evening.

16. Unloading Material.—If the outfit cars are not placed ahead the cars loaded with rails will then be at the front and one or two carloads of rails can be unloaded directly to the rail car by pulling them ahead on dollies, over the end of the head car. If, however, the outfit cars are in front, the rails must be unloaded from the sides of the cars. The unloading point should be selected where there is clear space beside the track, and as near as may be to the end of the track. The rails should not be thrown off the car bodily, as they are liable to be bent by such usage. It is a better plan to slide them off on skids, using for this purpose two pieces of rail, each about 10 ft. long, with a piece of the web and base cut away at the end and the projecting head bent over to hook into a stake pocket. To keep the rails off the ground, so as to make it easier to pick them up when loading the rail car, a tie should be laid at the foot of each skid, and if the ground is higher than the track it may be necessary to grease the skids. Four men able to handle themselves—two men working with rail forks (Engraving E, Fig. 295) and two with small pinch bars about 3½ ft. long—can slide off a carload of rails in about half the time that twice as many men can pick them up and throw them off the car, and, besides, no harm will be done the rails. If the rails are loaded upon gondolas the unloading force must be large enough to lift the rails over the side of the car. Wherever it is practicable the rails should be unloaded from both sides of the car. Rails for the far West are often shipped in box cars and must, therefore, be unloaded through the end of the car. In such cases it saves time to transfer the rails to flat cars before taking them to the front. This transferring can be most easily done in the yards, and the work can be much facilitated by first coupling the box cars alternately with the flat cars to be loaded.

Ties shipped long distances are usually loaded in box cars. They are more convenient for unloading if shipped on flat cars, and even cattle cars are more convenient for this purpose than box cars. As in the case with rails, the ties are unloaded from both sides of the cars wherever the ground is favorable. Unless the surroundings, such as grades, narrow embankments, etc., determine otherwise, materials sufficient for ¼ to ⅓ of a mile of track should be unloaded in a place. As soon as the material is unloaded the train is hauled back out of the way, but just before meal time, at noon and at evening, it is customary to run the train close up to the workmen.

17. Organization of Forces.—The work of track-laying may be analyzed into two distinct operations, namely: That of forwarding materials and laying them down at the front; and the work of joining these materials together and building the track structure. The methods pursued in the former operation have to do principally with the speed and cost of track-laying, and in the latter with the excellence of the track, for, on general principles, good track can be laid just as cheaply as poor track, if intelligent labor be employed and placed under competent supervision. In the organization of a track-laying crew there is usually a superintendent of construction, assisted by a clerk and three foremen. There is a foreman over tie distribution, a foreman with the rail car, and a foreman over the strappers and spikers. The clerk keeps the time of the men and looks after ordering and accounting for the camp supplies. Circumstances sometimes demand both a clerk and a timekeeper. If the work is done by contractors the railway company has its own superintendent or engineer, who is usually assisted by a clerk and an inspector or two, to see that material is not wasted and that the work is done properly and according to contract specifications. The number of inspectors required always depends a good deal upon the honesty and reliability of the contractor. There is also a receiver of material employed by the railway company, through whose hands all the track material must pass and be accounted for by the time it reaches the front.

The superintendent of construction usually gets about on horseback, and for convenience of communicating with headquarters it is a good plan to build the telegraph line as fast as the track-laying progresses. When this is done the superintendent of track-laying usually has a clerk who is a telegraph operator, and the line is temporarily connected with the office car and put in working order as often as the car is side-tracked, or every evening at the end of track if the outfit train is kept moving with the work. Usually there is a night watchman to take care of the locomotive, and sometimes another to look after the train and outfit. On extensive work, however, particularly when some distance out from the base of supplies, there is usually a night train crew to make up the material train for the following day's work and bring it to the front. The baking for a large crew, and sometimes part of the cooking, is done during the night by an extra force in the kitchen car.

18. Placing Ties.—The rapidity with which track can be laid depends, more than on anything else, upon the facilities for distributing the ties on the roadbed ahead of the men laying the steel. The most favorable conditions are to be found in a wooded country, where the ties can be got out along the route. In such case the ties should be delivered along the line and left in piles of a wagon-load each at about the proper distance apart to supply the required number. In a prairie country where hauling is good alongside the roadbed the best method is to distribute the ties with teams as they are unloaded from the train. If this cannot be done, and it is desired to rush matters, it may be found profitable to haul out along the roadbed each night enough ties to keep the steel men busy the following day. In order to keep the roadbed clear for hauling when following this plan the teams should haul to the far end first and work backwards toward the train, not attempting in any case to lay the ties to place during the night. The foreman in charge of the tie distribution can estimate nearly enough the number needed; and if not quite enough should be delivered a space can be left now and then to be filled after the track-laying is brought up. It will usually be found cheaper to distribute the ties with teams, if there is good opportunity to work them, than by any other method. Ten teams in one day can haul out the ties for a mile of track. The wagons should be coupled up short and provided with a sort of rack, so that a full load may be put on in a single pile. A V-shaped affair built on the order of a hay-rack is sometimes used. It saves much labor of handling to unload the ties from the cars to the wagons direct. A plank chute, with rollers, attached to the door posts, with the outer end slung from the top of the car, is sometimes used for passing the ties from the car to the wagons.

The usual method of distributing ties where teams are not employed is to haul the ties ahead on rail cars and carry them around to the front by hand. Eight or ten rails, base down, are placed upon the rail car and upon these are loaded 200 to 300 ties, crosswise the rails. This car-load of ties is hauled along close behind the car which is distributing the rails, so as to make the distance they have to be carried around as short as possible. If the ties are heavy this is a slow and expensive way of laying track, but if the ties are of light wood, not requiring more than one man to carry a tie, it does quite well, but never so well as the method of hauling them out with teams under fair conditions of wheeling. A modification of this method which has been practiced to some extent is to carry the rails, and ties enough to lay them, on the same material car. Ten rails are placed side by side on the rail car, and over the rails, and separated from them by side timbers on the car, are placed ties enough to lay the track as far as the rails will reach. In this way the rails may be unloaded regardless of the ties and the ties need not be carried farther than a rail's length in advance of the car.

The foreman of the tie distribution should see that the ties are distributed with some regard to the quality. For instance, if some of the ties are of harder wood, than others, it should be arranged to unload the harder ties for use together, and on the curves, as far as they will go, while the softer ties should be distributed on the tangents. It has sometimes occurred that cedar ties have been laid on curves and ties of fir or harder timber on the adjoining tangents.

As to the preparation of the roadbed for laying the ties, it is nonsense and a waste of time to smooth down the surface with planks or boards, after the manner of making an onion bed in a garden, or to set grade stakes every few feet and bed the ties to a straightedge laid across their upper faces. If the graders have done their work properly further attention is not usually required; but if the surface happens to be a little humpy or has been badly furrowed by wagon tracks a lively man or two working with pick and shovel can go in advance of the tie men and make the surface smooth enough for all practical purposes. If the ties vary much in thickness it is a good plan to have two men follow the spikers, one on each side of the track, to block or roughly tamp the ties to an even bearing before the outfit train comes on them. At such work as this it is well to detail lively men who are possessed of a little genius for grading; otherwise a great deal of time may be spent on the roadbed to but little purpose.

The ties are thrown down and then lined and spaced. If the faces of a tie vary in width the wider face should be placed downward, thus taking advantage of a larger bearing surface for the ballast. In lining the ties two men are given a stout cord or small rope about 1000 ft. long, called the tie line, which they stretch out and wrap around stakes set opposite every center stake at a distance of half the standard tie length. On curves the tie line should be staked about every 25 ft. On some roads it is the rule to line the ends of the ties on the south or east side of the track; on other roads they are lined on the side of the track on which the mile posts are located, and on many roads the inside of curves is always taken for the line side; but any question as to which is the proper side to line is of comparatively little consequence. On double track it conduces much to the appearance of things to always line the ties on the outside of both tracks. As the ties are laid down they are dropped approximately to the tie line, and the two men referred to, one working at each side of the track with a light pick, one end of which has been cut off near the eye (commonly known as a "picaroon"), pull the ties to the line and space them at the same time. It saves time to have a man with a sort of T-square gage turned down at the end so as to reach over and catch the end of the tie, measure from the long corner and mark across the face of each tie, on the line side, with a large plumbago pencil, a gage line for the edge of the rail base. This can be done rapidly, and it saves the spikers the trouble of gaging each tie to a notch on the hammer handle, as it is usually done. Among track-layers this man is known as the "fiddler." In some cases his tool consists of a piece of 6-in. board with a cleat across one end, to catch over the end of the tie, and a car door handle screwed on top, with which to carry it.

19. Spacing Ties.—It is economy to put plenty of timber under the rails. Within recognized limits of spacing an increase in the number of ties affords the track better support against deflection and against permanent settlement, the track is more easily maintained in alignment, the rails cut into the ties less and they are held to gage better on curves. Any increase in the number of ties provides a firmer support for the rails when the ties become old and begin to decay, and hence may slightly increase the life of ties in some cases. The application of these principles is independent of the weight of rail. Tie bearing surface will compensate to a considerable extent for deficiency in the size of rail section, or decrease in the number of ties when laying a heavier rail may lose to the track the advantages to be expected from the heavier and stiffer rail. There should be enough space between the ties to allow a shovel to be used to advantage, and this distance is at least 11 ins. in the clear. In the case of pole ties reference would be had to the distance between the cheeks or bulging sides. Such a spacing provides for about 17 pole ties of 6 to 8-in. face and 18 squared ties of 9-in. face, per 30-ft. rail. For main track it is now the standard practice with a number of roads to use 18 ties per 30-ft. rail, and a few roads use as many as 19. In numerous instances, however, the standard number is only 15, and on a comparatively few roads (where the average width of tie face is about 10 ins.) it is only 14, per 30-ft. rail. The number of ties used per rail length should depend upon their size and the spacing adopted. In the case of squared ties, all of which are usually of the same size, the number per rail length may be uniform and the spacing may be expressed as a certain distance measured from centers. In the case of pole ties, however, which are bound to vary in width of face, the number per rail length need not necessarily be constant, and a uniform center-to-center spacing does not afford the best distribution of the timber. As pointed out in discussing the size of ties (§ 10, Chap. II), the ideal distribution of rail support is a uniform proportion of tie bearing surface to rail length. Wherever the ties faces vary in width this equality of bearing surface is much more closely realized by a uniform spacing in the clear (regardless of the size of tie or the number per rail length) than by a uniform spacing between centers; and by making the spaces somewhat wider next the largest ties the desired distribution of rail support may be secured. If each tie separately had to bear the whole weight of the load passing over the rail then those parts of the rail resting upon the largest ties would be the better supported; but from the fact that the weight on the rail at any point is always distributed over several ties, and that as ties get smaller, if properly spaced, there are more of them for a given length of rail, the total amount of bearing or supporting surface for a given length is not after all very greatly affected by slight differences in widths of tie face.

No great heed need be given to the matter of spacing ties. Calculations or actual measurements need not be made. Men a little accustomed to the work will rapidly place the ties about the right distance apart, by the eye, without hardly taking thought. Ties should be placed squarely across the track, and never obliquely to suit joints which do not come exactly opposite. On curves it is usual to put the butt or wide end of the tie to the outside of the curve. It is the practice to some extent, however, to vary this arrangement to suit the class of traffic. Thus where the curve is to be elevated fully for fast passenger traffic the larger end of the tie would be placed under the inner rail, so as to give more supporting surface to resist the additional weight of freight trains thrown to that side of the track by reason of the slower speed. But if the freight traffic is the more important and the curves are elevated for a compromise speed, the larger ends are placed under the outer rail, so as to better resist the additional weight thrown upon that rail by passenger trains running at higher speed.

The spacing of ties at joints is a subject which seems to receive a great deal of attention—in some cases too much attention, so to speak, as in practice the matter may be overdone. In the first place there is nothing gained by crowding ties together at joints so closely that tamping, with bar, pick or shovel, cannot be freely done between them; in fact, such a congestion of support may amount to a weakness, by reason of inferior tamping. In the case of a suspended joint it is considered good practice to space the two joint ties as close as may be permitted without interfering with the use of a raising jack and the effective use of tamping tools, which is about 8 ins. in the clear. The shoulder ties, however, should not be spaced so close to the joint ties as to interfere with the free use of a shovel between them. At supported joints it is quite commonly the practice to space the two shoulder ties as close to the joint ties as is practicable without interfering with the free operation of tamping tools. Outside of these three ties, however, spaces too narrow for free shoveling should not be allowed: the extra bearing secured will not compensate for what is lost through inconvenience in removing the ballast when renewing the ties. In connection with the use of long splice bars (the so-called "three-tie joint") one may frequently find the three ties under the splice spaced too close for effective tamping. One object in spacing so closely in such cases is to bring the two shoulder ties (sometimes, but improperly, called joint ties) entirely under the splice bars for the purpose of slot spiking. To follow out this plan under splice bars less than 42 ins. long makes the spaces on either side of the joint tie too narrow. On some European roads where it is the practice to reduce the spacing of the ties in the vicinity of the joint to the smallest practicable limit, room for the use of tamping tools is provided for by chamfering off the upper corners of the ties, outside the rail seat. Where rail creeping is not bothersome some advantage may be derived by selecting the widest ties for the joints, as in that way the proportion of bearing surface to the minimum allowable spacing may be increased. For the same reason the butt or wider end of joint ties may be turned to the joint side, on broken-jointed track. At suspended joints on double track it is largely the practice to put the largest tie under the shoulder at the receiving rail end or "facing" end, as it is sometimes called. On some of the European railways the same object is aimed at by an unsymmetrical arrangement of the ties at the joint, whereby the support for the receiving rail end is brought closer to the joint than that for the leaving rail end, so as to better meet the greater stress.

In American practice it is customary to space intermediate ties evenly or as nearly uniform as may be permitted by the variations in the size of pole ties. Theoretically the spaces should vary to gradually increase the ratio of tie bearing surface approaching the weakest points of the rails, which are the joints. This principle is extensively followed in European practice, the spaces being gradually increased from the joints into the quarters. Thus, in one case the center-to-center spacing increases from 16 ins. at the suspended joint, to 22 ins. for the shoulder ties and 33 ins. for the remainder of the intermediate ties. In another case the spacings run 19½—26½—31½—33½ ins. centers; and in another 19½—21½—21½—31½ ins. c. to c. of ties. It is understood, of course, that any advantages obtainable by varying the tie spacings near the joints apply only to square-jointed track, or where the joints come opposite. The bunching of ties at and near the joints on broken-jointed track bunches them likewise at the centers and quarters of the rails opposite, so that the intermediate portions of the rails get the same extra support as do the joints, and no advantage is gained. The same considerations have a bearing upon the question of sorting out the largest ties for the joints—on broken-jointed track they strengthen the support for the rail center as much as for the joints.

In order to space the ties with reference to the joints, in advance of the laying of the rails, a light pole as long as the standard rail is trailed along over the ties and the proper locations for the joint ties are measured off. In laying the Columbia & Western branch of the Canadian Pacific Ry. a piece of band iron 30 ft. long, with a ring on the front end, to pull it along, and copper rivets at intervals corresponding to the tie spaces, was used for this purpose. The use of a spacing pole or line requires the attention of two men and gives a good deal of bother. Where the rails are laid broken jointed, requiring the arrangement of two sets of joint ties in each rail length, it is better to let the tie spacing go, except roughly, until after the rails are laid down—and it is perhaps the better plan in any case. Two men working with picks and two men with bars to lift the rails, can then space the joint ties and divide up the other spaces to conform thereto. Owing to variation in rough measurements the joint ties should not, in any event, be located far ahead of the rails. To avoid discrepancies and the necessity for rearranging the ties at intervals the pole measurements should be checked occasionally by referring back to the rails.

20. Supported or Suspended Joints?—Properly speaking, the term joint, as applied to track, refers to the junction or meeting point of two rails; at ordinary temperatures it is usually an open space. There are two ways of spacing ties with reference to the joint. A supported joint, as understood among trackmen, is one where the rail ends meet upon a tie; a suspended joint is one which hangs in the clear between two ties. All joints are therefore either supported or suspended, but it is usually the aim in spacing joint ties to have the joint come approximately over the middle of the tie, in the case of the supported joint, and about midway between a pair of ties, in the case of a suspended joint. Since long splice bars have come into use the term "three-tie" joint has gained currency. Such, however, is only another name for a supported joint, the "three-tie" idea arising from the fact that the splice extends over three ties. Strictly speaking, the two outer ties of such a group are not joint ties, because they lie neither under the joint nor adjacent to it. For the sake of accuracy the terms joint and splice should not be used interchangeably; nevertheless their use in this manner is pretty general.

As already pointed out, a scientific investigation of the supporting strength of joint splices is perplexed with so many practical difficulties that recognized theories fail of application. Such is also the case with the question as to the merits of supported and suspended joints. So far as concerns the matter of support, observing trackmen are about evenly divided in their opinions as to results. It is a fair supposition, therefore, that any advantages one way or the other must be small. Aside from the question of support, however, there are other considerations deemed to be more or less important which have weight in determining practice. One of these is the facility of suspended joints to the slot-spiking of the splice bars against creeping rails. At a suspended joint it is always practicable to provide for slot-spiking two ties, whereas at a supported joint the splice bars must be long enough to extend over three ties in order to slot-spike at all, unless resort be had to the objectionable practice of slotting or punching the splice bars near their middle. These facts will very likely account for the predominance of the suspended joint on American railroads. At any rate it appears significant that where short splices are in service the suspended joint is generally standard. A summary of the practice of 50 representative American railroads, from data on angle-bar splices collected in the year 1900, shows that the suspended joint was standard on 39 roads and the supported joint on 11 roads. Out of the 39 roads referred to only seven had standard splices longer than 30 ins., and the average length of the standard splices of all these roads was 27.4 ins. Of the 11 roads on which the supported joint was standard only three had standard splices less than 36 ins. long, and the average length of the standard splices of all these roads was 34.2 ins. It is commonly the case, therefore, that the splice bars of supported joints are long enough to permit of slot-spiking the two shoulder ties, whereas the average length of splice bar at suspended joints is not sufficient to permit of slot-spiking at its ends if used with a supported joint.

The stock arguments for and against either type of joint under consideration are quite widely known, but for the sake of completeness a few more of them may bear repeating. Those who stand for the supported joint claim that the rail is supported at its weakest point, but, since the support is yielding and not a permanent one, by any means, all know that it is depressed when the load comes on; still it seems like getting the support, such as it is, at the right place. In the case of a joint splice broken at the center (which is equivalent to a broken rail) the supported joint is undoubtedly the safer at any season of the year, and particularly so in the winter, when splice bars are most liable to break. When the ballast is frozen up solid a tie directly under the joint should afford much better support to the rail ends than the two ties as arranged for a suspended joint. A suspended joint with the splice bars broken at the center is equivalent to a rail broken between two ties, which is always considered very dangerous.

It is claimed for the suspended joint that the rail ends are supported at the middle of the splice, which distributes the load upon the joint to two ties, instead of one, and when the joint is depressed both rail ends are carried down evenly. It is readily seen, however, that these advantages do not obtain with a loose or badly worn splice; besides, the distribution of the load upon a joint does not fall entirely upon the joint ties, being partly carried by the shoulder ties, and we have no means of ascertaining just what portion of the load is sustained by the ties which take part in the support of the rail ends at either a supported or suspended joint. A worthy attempt at a mathematical determination (approximately, of course) of the "Relative Strength of Suspended and Supported Angle-Bar Joints" is recorded in a paper prepared for the Association of Engineers of Maintenance of Way of the Pennsylvania Lines West of Pittsburg, in 1896, by Mr. J. C. Bland, then principal assistant engineer of the Pittsburg, Cincinnati, Chicago & St. Louis Ry. It is further claimed for the suspended joint that, hanging clear as it does, it does not permit the collection of dirt or other material to hinder the proper expansion of the rails.

In my private opinion most of the labor and care of spacing joint ties symmetrically with respect to the joint amounts to nothing in the end. As the joint is the weakest part of the rail the heaviest pressure on the ties occurs at this point, in the case of a supported joint, and in the vicinity of this point in the case of a suspended joint. The idea in the symmetrical arrangement of the ties is, of course, to equalize the rail pressure on ties occupying corresponding positions on either side of the joint. If we could solve the rail joint problem on the theory of continuous beams, cantilevers and solid supports we could then figure out the distribution of rail pressure to a nicety; but when we come to consider that the shoulder ties, as well as the joint ties, have some part in the joint support, and that the rail under each wheel load is depressed over a distance extending several feet each way from the joint, the aspect of the situation is then not so precise. If the ties are properly spaced, any hit-or-miss location of the joint cannot depart more than 5 ins. from a symmetrical position with reference to them; that is, it cannot be more than 5 ins. from the position of either a supported or a suspended joint. This possible difference (which would not occur in every case if ties were spaced irrespective of the joints) is such a small fraction of the span of depression that any variation of the distribution of rail pressure due to this cause, when the splice is holding properly to its duty, must be indeed small, particularly in the case of a long splice. If the splice be loose or worn, so that it cannot perform its function, the joint is necessarily a shaky affair, in any case, and a choice as between a symmetrical and nonsymmetrical arrangement of the ties then falls between "six for one and a half dozen for the other." Coming to actual practice, what is the usual condition of things, even where the ties as originally laid were arranged very carefully with respect to symmetry with the joint? Where splices are slot-spiked the creeping of the rail crowds the joint and shoulder ties together on one side of the joint and pulls them apart on the other, leaving the bearing surface badly distributed. If the ties are moved back to their proper spacing their position with respect to the joint is necessarily changed. In this way joints which were originally supported "get suspended," or vice versa, and it is mere luck and chance if the new arrangement brings the ties into positions symmetrical with the joint—such can occur only where the rail happens to creep a distance corresponding to half the spacing interval. If the splices are not slot-spiked the creeping of the rail will soon carry the joints out of any prearranged position with respect to the ties, and leave the big joint ties behind on the shoulders. This matter of rail creeping, wherever it occurs (and it occurs pretty generally), renders it impracticable to maintain any desired arrangement of joint and shoulder ties without continually respacing them or pulling the rails back. It is actually a fact that thousands of miles of track in this country would be in much better condition to-day if the ties in the first instance had been spaced without reference to the joints and no attempt had been made to pick out the largest ties for the joints.

21. The Rail Car.—From the point where the materials are unloaded from the construction train the rails, and in some cases the ties, are hauled ahead on strongly-built cars known as "rail cars," also commonly called "iron cars" and "steel cars." The car is usually about 8 ft. long, with 4x8-in. side sills and four cross pieces, and it should carry a load of 15 to 18 tons, or say, forty or forty-five 80-lb. rails. On both ends of the car, near each corner, there should be a roller, for use in unloading the rails. Planks are sometimes nailed to the under side of the frame, between the two middle cross pieces, to form the bottom of a box for carrying tools and small supplies. The wheels are usually about 16 ins. in diam. and the treads of the same should be 7 or 8 ins. wide, so that the car may be safely run over loosely-lying rails, before the track is spiked. If the wheel treads are narrow in a case of this kind it requires a great deal of care to keep them from dropping between the rails on curves. A rail car off the track, with a load of rails aboard, is often the cause of serious delay to the whole work. The axles should be as large as 2¾ or 3 ins. in diam., and the wheels should be spoked, so that they can be spragged in emergency. For hitching the team to the car there should be a large ring eye-bolted to each side sill at the middle. For hauling rails it is usual to have a team of two horses hitched in tandem, the driver riding the hind horse and driving the one ahead. In this way they pull close beside the track, on a rope 25 to 30 ft. long, and are driven at a trot when returning with the empty car. A man with brake stick should always ride the car and be ready to unhook the rope in case the car should get the start of the team.

22. Placing Rails.—As the limit to the length of track that can be laid in a day, after the ties have been placed, is fixed only by the rapidity with which the rails can be laid down, much depends upon the skill acquired by the rail car gang in handling rails. The succession of movements in laying the rails to place is about as follows: There is a man with a wheel chock to stop the car at the right place at every move ahead. There is a squad of five men (more or less, according to the weight of the rail) near the head end of the rail who seize it in their hands and carry it ahead as soon as the car stops; after a little practice they pull the rail off so as to drop it almost to place. Two men, known as "heeler" and "hip heeler," at the rear end of the rail, move it in line with the rail behind; the heeler inserts an expansion shim; the men at the head end give the rail a pull backwards, to close up on the shim; one man who watches the rails for lip carries a bar, to hold the end of any rail in line, in case of necessity, and the car is pushed ahead. A clamp gage is sometimes used on the rails ahead of the car to keep them from spreading, especially on curves. Where quick work is desired there are two parties handling rails, unloading from both sides of the car at the same time. The opportunity to do this is not so favorable if the rails are laid broken jointed, which is the reason that contractors prefer to lay them square jointed. On track with but few curves greater speed can be made in laying rails square jointed than when laying them broken jointed, because there is not so much starting and stopping of the car.

One rail car can handle the rails for laying a mile of track per day. In fast work two rail cars are used. One of the cars is loaded while the other is being unloaded, and in order to get the loaded car past the empty one, when pulling the loaded car to the front, the empty car is turned up on its side, on the ties, outside the rail, and held there or tilted back and propped in a leaning position while the loaded car is passing. A portable turntable has sometimes been used for this purpose. The men with the rail-laying car come back with the empty car each time as far as the point where it is passed by the loaded one coming out, but if the work is properly managed they should pass near the front, thus delaying the rail-laying crew as little as possible. The crew at the rear should be large enough to unload the material, curve the rails, if necessary, load the ties and the rail cars and keep things moving at the front. In some cases where the ties are hauled ahead by teams the rail cars are loaded by the rail-laying crew. Where such is the practice it pays to load up two cars with rails, before starting out, and take them both to the front. After the first car has been unloaded it is taken off the track and the second car is run forward and unloaded. This arrangement saves the time that would otherwise be lost in taking the crew back to load and return with the second car, and it gives the material train a chance to run back and do switching. On every car-load of rails hauled ahead enough splices, bolts and spikes are taken to lay the rails. The splices are thrown off at every joint passed and spikes and bolts, in the original kegs or boxes, at such intervals as they are needed. In some instances the heelers attend to dropping off the fastenings.

In laying track around curves the inner rail gains upon the outer rail at the rate of about 1.03 ins. per 100 ft. per degree of curvature. Provision should therefore be made to lay enough short rails on the inner side of the curve to compensate for this gain. In practice such rails are seldom shortened more than 1 ft., but a shortening of about 6 ins. is considered preferable, as then the relative position of the joints on the two sides of the track need not change so much. It is most convenient to crop the rails with a view to save one or two bolt holes, which will usually shorten the rail about 6 ins. If 29½ ft. is the length of the short rail used each one so laid should be placed when the inner rail has gained 3 ins., instead of waiting until it has gained all of the 6 ins., as then the joints on opposite sides need not get more than 3 ins. out of the desired relative position. If the tangent beyond the curve is laid square-jointed, the last short rail laid in the curve (or the only one in a short curve) should be cut to such length that it will bring the joints even at the end of the curve, whether it comes the standard length for the short rail or not. The short rails for use on curves are usually loaded with the rest and are designated by some mark, such as a band of white paint around the rail or by painting the end of the rail white, or both.

It is not considered standard practice to lay in main track a piece of rail shorter than 14 ft. Gaps shorter than this are closed by taking out a rail of full length and using two cut rails as "closers" for the whole distance. As an example, suppose that a gap of 10 ft. is to be closed. Taking out a whole rail leaves a gap of 40 ft., which is closed by laying two 20-ft. pieces or two pieces of other convenient lengths, neither being shorter than 14 ft. On the outer side of curves it is not desirable to use short lengths at all, especially pieces shorter than 20 ft. On short curves it is an easy matter to avoid the use of a short piece by slipping the rails back to carry the gap ahead to the tangent. Short lengths of rail laid on either side of a curve should be curved before laying, whether the rails of full length laid on the curve are so prepared or not. To secure a proper fit for the splice bars the ends of any rails which may have become burred, by sawing or other cause, should be filed smooth on the fishing surfaces. For this purpose sharp cold chisels and large bastard-cut files are useful. The same treatment should be applied to splice bars burred at the ends.

23. Square or Broken Joints?—There are two ways of laying rails with reference to the relative position of the joints on opposite sides of the track. When the joints are directly opposite, or nearly so, the track is called "even jointed" or "square jointed;" when the joint on one side comes opposite the middle of the rail on the other side, or thereabouts, the track is said to be laid "broken jointed." Of course, track not laid even jointed would be broken jointed whether the joint on one side came opposite the middle of a rail on the other side or not, but broken-jointed track is usually laid in the manner stated. Practically, it is immaterial whether the joint on one side comes exactly opposite the center of the rail on the other side or not. If joint splices performed their duty to entire satisfaction it would not matter which way rails were laid—square jointed or broken jointed—but under conditions as they exist some question arises as to the merits of the two ways of arranging the joints. With broken joints the track structure possesses a greater continuity of strength to hold it in alignment than is the case with square joints, because at all points there is a solid rail on at least one side. Track, especially on curves, will hold in line better if it is laid broken jointed, and the necessity for curving rails on curves of long radius is then not so great. Where it is intended to keep the road in first-class order there can be no doubt but that broken-jointed track is the easier to maintain in good condition.

Even or square-jointed track is found principally in the West. It is a familiar argument that on long lines where the traffic is light and where it is considered unprofitable to maintain track surface in first-class condition, square joints are preferable; since the roughest parts of the track are found at the joints it is better to have them opposite, so that both wheels on the same axle drop at the same instant, thus avoiding the swinging motion to the car which occurs where the low places alternate, as on broken-jointed track. On the other hand the necessity for raising low joints on square-jointed track may be so far lost sight of that the surface will become excessively bad and the cars go hopping over the line. The motion is a teetering one, unpleasant to passengers, destructive of draft rigging and severe upon the track, for if both sides of the car truck pound the track at the same time the track is struck a heavier blow than is the case if the action is alternating from side to side. Low joints on broken-jointed track, if not excessively out of surface, become less noticeable as the speed of the car increases, owing to the fact that the car body has not time to make a full oscillation to one side before it is under a tendency to swing the other way. One explanation for the existence of a great deal of even-jointed track on roads that are comparatively straight, is that the contractor for the track-laying understood his business better than the railway official in charge knew the company's business, for as heretofore explained, it is somewhat cheaper, under these conditions, to lay the joints even than to lay them broken; and on straight line contractors prefer to lay them that way—it is one of the measures in track-laying which makes for haste. Where curves are numerous it is cheaper to lay the rails broken jointed, as otherwise a good deal of time is lost in squaring the joints. On broken-jointed track it is not necessary to keep the joint on one side exactly opposite center of rail on the other side, and hence on curves the inner rail may be permitted to run ahead until the short rail of standard length (28 ft., 29 ft. or 29½ ft.) will compensate for the difference. On square-jointed track this could not be done. Square joints are standard on but comparatively few roads. There are some who think that on new lines not well ballasted square joints are preferable while the banks are settling, and others claim to prefer square joints where the track heaves badly in winter. On the Atchison, Topeka & Santa Fe Ry. even joints are standard for track on earth filling and broken joints for track on ballast.

The superior arrangement of broken joints for holding the alignment on curves has been recognized in the practice of a number of roads where a double standard is maintained—broken joints for curves and even joints for the tangents. Where this practice is followed the matter of keeping the joints on the curves directly over against the centers of the opposite rails is not always insisted upon, and on short curves the joints on the inner rail are allowed to run ahead of their regular positions until the tangent is reached, where a cut rail is laid to square the joints. In passing from even to broken joints in entering a curve, or vice versa, upon leaving the curve, the work need not be delayed to await the cutting of a rail, for the changed arrangement of the joints may be started and the connection made temporarily by turning out the end of a whole rail and laying a switch point. A rail may then be cut at convenience to fill the gap, and the spare piece from the rail so cut should be taken ahead to the other end of the curve, or else to the next curve. If the curves are only a short distance apart (say less than 1000 ft.) it is usual, where the practice of changing the relation of the joints at curves is followed, to continue the broken joints throughout the intervening tangents.

Touching the question of square or broken joints for double track, arguments are presented both ways. Some prefer square joints in order to keep the joint ties square when the rails creep. If the rails creep on broken-jointed track the joint ties are slewed out of square and the rails are pulled out of gage and alignment. This difficulty may be overcome, however, by putting anchor splices or anti-creepers on the solid rail opposite the joint. Others prefer broken joints for the reason that, with traffic in one direction, one rail will generally creep more than the other, and if the joints are laid even to start with, it is only a little while until the joint ties become slewed out of square, making it necessary to drive one of the rails back, to bring the joints opposite and straighten the ties around.

24. Curving Rails.—The rules of various roads require that the rails for curves of 2 to 4 deg. and over (most frequently 3 deg. and over) shall be curved before laying. In practice, however, it is quite frequently the case that rails for curves much sharper than 4 deg. are laid without curving. As to the limit of curvature up to which rails may be laid without curving there is a simple experiment which I think may serve as a rough guide to practice, and that is to ascertain what curvature the rail will hold of its own weight. For instance, a straight 60-lb. rail 30 ft. long resting loosely upon the ties, simply by its own weight, will lie to a curve having a middle ordinate of 1 in., without spikes or other means to hold it in place. The 1-in. middle ordinate corresponds to a curve of 4¼ deg. Such being the facts there would seem to be no question but that 60-lb. rails spiked to ties would hold considerably more curvature, or lie to a curve of say at least 6 or 7 deg., without being curved. As the work of curving rails is expensive, costing, by the usual methods, $35 to $60 or more per mile of curved track, the necessity for the same should be carefully considered.

The conditions which have a bearing upon the question are the length of rail and the weight per yard, the efficiency of the joint splices in the way of lateral stiffness, the manner of laying the rails with respect to the relative position of the joints, the weight of the ties and the manner of filling in and dressing off the ballast. The longer the rail the less the necessity for curving, for obvious reasons. In practice it has been found that 45-ft. and 60-ft. rails could be laid without curving, on the same curves where it had always been considered necessary to curve the 30-ft rails laid thereon. Increase in weight of rail increases the necessity for curving, other conditions the same. The tendency of uncurved rails to straighten when laid on sharp curves would not necessitate curving were it not for the weakness of the rail at the joint. A rail sprung to the curve is more rigid than one curved or bent so that it will lie to place of itself; and if such rigidity could be maintained continuously the track would be better able to hold its shape or alignment against

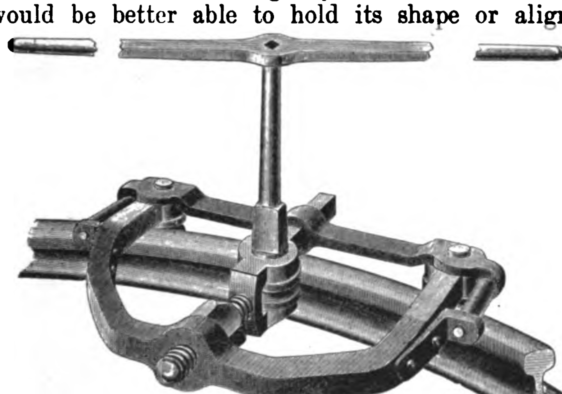


Fig. 31.—Rail-Curving Machine.

side pressure from wheel flanges; that is, if it was practicable to make rails continuous it would be better not to curve them for track of any degree of curvature. A bow pulled to the point of shooting the arrow is more rigid than it is when not strung up, and the same principle applies in some degree to rails laid on curves. If, however, the splice fails to perform its duty properly, as is usually the case with short splices, splice bars of light section or with splices which have become loose, the rail will bend at this point and relieve itself of stress, and uniformity of curvature will not be maintained. For reasons made clear in the previous section the superior alignment conditions of broken-jointed track will permit uncurved rails to be laid to sharper curvature on such track than is the case with track on which the joints are laid opposite. It is unnecessary to explain how heavy ties and the filling of ballast around the ties, especially against the ends of the same, assist in holding the track to the proper curvature, regardless of any question of curving the rails.

Rail-Curving Devices.—A rail-curving machine consists essentially of three rolls so positioned that the rail is made to pass between two rolls on one side and a roll on the opposite side placed midway between the other two. By tightening down on the middle roll, which is adjustable, the rail is bent uniformly to a curve as it passes through, the desired curvature being obtained by properly setting the middle roll. The best results are to be had by the use of rolls shouldered to fit against both the head and web of the rail. On some roads these machines are placed in the shops and operated by steam power, but the use of hand machines is more extensive. A hand machine of this description is shown as Fig. 31, being what might be called a traveling jim-crow. It has a heavy forged yoke or frame carrying three grooved curving rolls, the middle one being adjustable by means of a screw and provided with means whereby it may be revolved—in this case a heavy box wrench and a lever. The rail stands workwise, with a plank alongside to support the frame, and as the middle roll is turned it travels along on the rail, curving the rail as it moves. Two to 6 men, depending on the weight of the rail and the amount of curvature given, are required to operate it; and, working in this manner, about 50 rails can be curved in 10 hours. In the proceedings of the New England Roadmasters' Assn. for 1896 it is stated that 20 men working with a machine of this kind curved one hundred 100-lb. rails in 10 hours. To expedite matters the machine is sometimes made stationary by chaining it to the ties, in the middle of the track, and the rails are hauled through with a locomotive and switch rope. In one instance of this kind there were two gangs of men—one carrying rails to the machine and another carrying them away as fast as the locomotive could pull them through. By this method the

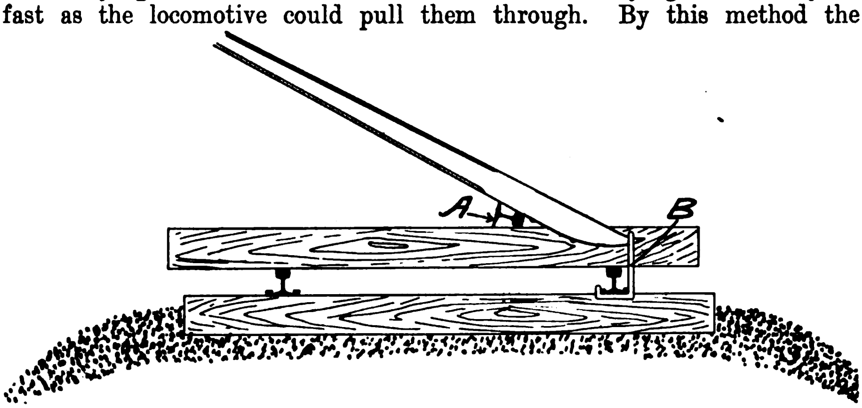


Fig. 32.—Lever and Hook Arrangement for Curving Rails.

rails were curved at an average rate of one each minute. The machine may also be fitted with a horse-power attachment intended for heavy work. It consists simply in a 7-ft. lever fitting the square shaft of the middle roll, the horse traveling around at the end of the lever.

The most rapid method of curving rails by hand is by the use of levers and sledges. The crew for this work should be large enough to pick up a rail and carry it easily in the hands—say ten men for 80-lb. rails. The rails are unloaded onto skids alongside some side-track. Two ties are then placed on and across the rails of the side-track a rail's length apart, and the rail to be curved is placed upon these two ties, on its side. The rail to be curved is then put under strain by bending it downward with two levers placed at about the quarter points and secured to the track rail by means of an inverted U-shaped iron with a hook on the lower end of each leg to fit under the base of the track rail. Figure 32 shows the arrangement, *A* being the rail to be curved and *B* the device for anchoring the lever, known as a "curving hook." In the absence of this hook a piece of chain is substituted. In lieu of a side-track for anchoring the levers two rails may be thrown down loosely across some ties. The rail is curved by striking it a few times, in its strained position, on the side of the head, just outside where the two levers are resting, with two 16 or 18-lb. sledges. The rail is then turned workwise and a string is stretched to see if the middle ordinate corresponds to the proper curvature. In case the rail should be curved too much some curvature may be taken out easily by turning the rail on its side, curve up, and springing down upon it with a teetering motion a few times; this is called "shaking" out the curvature. Rails can in this manner be cheaply and well curved. If the curvature does not seem to be uniform throughout the length of the rail the position of the levers should be slightly changed. After ascertaining the proper positions for the levers, and by always bearing down upon them with the proper amount of force and striking firm, steady blows, men can soon become so skillful that a certain number of blows each time will curve the rail so nearly right that it will not be found necessary to measure the middle ordinate every time; but the foreman should measure one occasionally to correct his eye. Sometimes only one lever is used, at the middle of the rail, but this arrangement does not give as good satisfaction as that of using two levers and two sledges in the manner stated. The curvature of the rail may be tested for uniformity by measuring the quarter ordinates, which should be three fourths the length of the middle ordinate with the string in the same position; that is, stretched the whole length of the rail. Another way to test for uniform curvature, best adapted to rails curved to a short radius, is to stretch a string over each third of the rail to see if the middle ordinate is the same in every case.

The lever-and-sledge method of curving rails is widely in disfavor, owing to the "barbarous treatment" which the rail is supposed to receive. On this point it is pertinent to inquire how a rail liable to injury by a side blow from a sledge hammer can be expected to stand the heavy alternating stresses imposed by fast locomotives and the heavy pounding of

Table IV.—Middle Ordinates for Curving Rails.

Degree of Curve	Radius.	LENGIH OF RAILS.										
		30	28	26	24	22	20	18	16	14	12	10
	Feet.	In.	In.	In.	In.	In.	In	In.	In.	In.	In.	In.
1.	5730	$\frac{15}{64}$	$\frac{3}{16}$	$\frac{5}{32}$	$\frac{1}{8}$	$\frac{7}{64}$	$\frac{3}{32}$	$\frac{5}{64}$	$\frac{1}{16}$	$\frac{1}{32}$	$\frac{1}{32}$	$\frac{1}{64}$
1.5	3820	$\frac{11}{32}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{7}{32}$	$\frac{3}{16}$	$\frac{5}{32}$	$\frac{1}{8}$	$\frac{3}{32}$	$\frac{1}{16}$	$\frac{3}{64}$	$\frac{1}{32}$
2.	2865	$\frac{29}{64}$	$\frac{13}{32}$	$\frac{11}{32}$	$\frac{19}{64}$	$\frac{1}{4}$	$\frac{13}{64}$	$\frac{5}{32}$	$\frac{1}{8}$	$\frac{3}{32}$	$\frac{5}{64}$	$\frac{3}{64}$
2.5	2292	$\frac{37}{64}$	$\frac{33}{64}$	$\frac{7}{16}$	$\frac{3}{8}$	$\frac{21}{64}$	$\frac{17}{64}$	$\frac{7}{32}$	$\frac{11}{64}$	$\frac{1}{8}$	$\frac{3}{32}$	$\frac{1}{16}$
3.	1910	$\frac{11}{16}$	$\frac{39}{64}$	$\frac{17}{32}$	$\frac{7}{16}$	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{17}{64}$	$\frac{13}{64}$	$\frac{9}{64}$	$\frac{7}{64}$	$\frac{5}{64}$
3.5	1637	$\frac{27}{32}$	$\frac{47}{64}$	$\frac{5}{8}$	$\frac{33}{64}$	$\frac{7}{16}$	$\frac{3}{8}$	$\frac{19}{64}$	$\frac{15}{64}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{3}{32}$
4.	1433	$\frac{61}{64}$	$\frac{53}{64}$	$\frac{23}{32}$	$\frac{19}{32}$	$\frac{1}{2}$	$\frac{27}{64}$	$\frac{11}{32}$	$\frac{9}{32}$	$\frac{7}{32}$	$\frac{5}{32}$	$\frac{7}{64}$
4.5	1274	$1\frac{1}{16}$	$\frac{59}{64}$	$\frac{13}{16}$	$\frac{43}{64}$	$\frac{9}{16}$	$\frac{15}{32}$	$\frac{25}{64}$	$\frac{5}{16}$	$\frac{15}{64}$	$\frac{3}{16}$	$\frac{1}{8}$
5.	1146	$1\frac{3}{16}$	$1\frac{1}{32}$	$\frac{57}{64}$	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{17}{32}$	$\frac{27}{64}$	$\frac{11}{32}$	$\frac{17}{64}$	$\frac{13}{64}$	$\frac{9}{64}$
5.5	1042	$1\frac{19}{64}$	$1\frac{1}{8}$	$\frac{63}{64}$	$\frac{27}{32}$	$\frac{45}{64}$	$\frac{37}{64}$	$\frac{15}{32}$	$\frac{3}{8}$	$\frac{9}{32}$	$\frac{7}{32}$	$\frac{5}{32}$
6.	955.4	$1\frac{13}{32}$	$1\frac{7}{32}$	$1\frac{1}{16}$	$\frac{29}{32}$	$\frac{49}{64}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{13}{32}$	$\frac{5}{16}$	$\frac{15}{64}$	$\frac{5}{32}$
6.5	882	$1\frac{17}{32}$	$1\frac{11}{32}$	$1\frac{11}{64}$	$\frac{63}{64}$	$\frac{53}{64}$	$\frac{11}{16}$	$\frac{35}{64}$	$\frac{7}{16}$	$\frac{21}{64}$	$\frac{1}{4}$	$\frac{11}{64}$
7.	819	$1\frac{21}{32}$	$1\frac{7}{16}$	$1\frac{1}{4}$	$1\frac{1}{16}$	$\frac{57}{64}$	$\frac{47}{64}$	$\frac{19}{32}$	$\frac{15}{32}$	$\frac{23}{64}$	$\frac{17}{64}$	$\frac{3}{16}$
7.5	764.5	$1\frac{3}{4}$	$1\frac{33}{64}$	$1\frac{21}{64}$	$1\frac{1}{8}$	$\frac{61}{64}$	$\frac{25}{32}$	$\frac{41}{64}$	$\frac{1}{2}$	$\frac{25}{64}$	$\frac{9}{32}$	$\frac{3}{16}$
8.	716.8	$1\frac{7}{8}$	$1\frac{41}{64}$	$1\frac{27}{64}$	$1\frac{13}{64}$	$1\frac{1}{64}$	$\frac{27}{32}$	$\frac{43}{64}$	$\frac{17}{32}$	$\frac{13}{32}$	$\frac{19}{64}$	$\frac{13}{64}$
8.5	674.6	2	$1\frac{47}{64}$	$1\frac{33}{64}$	$1\frac{17}{64}$	$1\frac{5}{64}$	$\frac{57}{64}$	$\frac{23}{32}$	$\frac{37}{64}$	$\frac{7}{16}$	$\frac{21}{64}$	$\frac{7}{32}$
9.	637.3	$2\frac{3}{32}$	$1\frac{53}{64}$	$1\frac{19}{32}$	$1\frac{11}{32}$	$1\frac{9}{64}$	$\frac{15}{16}$	$\frac{3}{4}$	$\frac{39}{64}$	$\frac{29}{64}$	$\frac{11}{32}$	$\frac{15}{64}$
9.5	603.8	$2\frac{15}{64}$	$1\frac{61}{64}$	$1\frac{11}{16}$	$1\frac{27}{64}$	$1\frac{7}{32}$	1	$\frac{13}{16}$	$\frac{41}{64}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{4}$
10.	573.7	$2\frac{11}{32}$	$2\frac{3}{64}$	$1\frac{25}{32}$	$1\frac{1}{2}$	$1\frac{17}{64}$	$1\frac{3}{64}$	$\frac{55}{64}$	$\frac{11}{16}$	$\frac{35}{64}$	$\frac{25}{64}$	$\frac{17}{64}$
11.	521.7	$2\frac{19}{32}$	$2\frac{1}{4}$	$1\frac{61}{64}$	$1\frac{43}{64}$	$1\frac{13}{32}$	$1\frac{5}{32}$	$\frac{15}{16}$	$\frac{3}{4}$	$\frac{9}{16}$	$\frac{7}{16}$	$\frac{9}{32}$
12.	478.3	$2\frac{13}{16}$	$2\frac{15}{32}$	$2\frac{9}{64}$	$1\frac{13}{16}$	$1\frac{17}{32}$	$1\frac{17}{64}$	$1\frac{1}{64}$	$\frac{53}{64}$	$\frac{41}{64}$	$\frac{15}{32}$	$\frac{5}{16}$
13.	441.7	$3\frac{3}{64}$	$2\frac{21}{32}$	$2\frac{9}{32}$	$1\frac{61}{64}$	$1\frac{21}{32}$	$1\frac{23}{64}$	$1\frac{7}{64}$	$\frac{29}{32}$	$\frac{11}{16}$	$\frac{1}{2}$	$\frac{21}{64}$
14.	410.3	$3\frac{5}{16}$	$2\frac{55}{64}$	$2\frac{31}{64}$	$2\frac{3}{32}$	$1\frac{25}{32}$	$1\frac{15}{32}$	$1\frac{3}{16}$	$\frac{61}{64}$	$\frac{47}{64}$	$\frac{35}{64}$	$\frac{23}{64}$
15.	383.1	$3\frac{35}{64}$	$3\frac{5}{64}$	$2\frac{43}{64}$	$2\frac{1}{4}$	$1\frac{29}{32}$	$1\frac{37}{64}$	$1\frac{17}{64}$	$1\frac{1}{64}$	$\frac{25}{32}$	$\frac{19}{32}$	$\frac{25}{64}$
16.	359.3	$3\frac{3}{4}$	$3\frac{9}{32}$	$2\frac{53}{64}$	$2\frac{13}{32}$	$2\frac{3}{64}$	$1\frac{43}{64}$	$1\frac{23}{64}$	$1\frac{3}{32}$	$\frac{27}{32}$	$\frac{5}{8}$	$\frac{27}{64}$
17.	338.3	4	$3\frac{31}{64}$	$3\frac{1}{32}$	$2\frac{9}{16}$	$2\frac{5}{32}$	$1\frac{25}{32}$	$1\frac{7}{16}$	$1\frac{5}{32}$	$\frac{57}{64}$	$\frac{21}{32}$	$\frac{7}{16}$
18.	319.6	$4\frac{7}{32}$	$3\frac{43}{64}$	$3\frac{3}{16}$	$2\frac{45}{64}$	$2\frac{9}{32}$	$1\frac{7}{8}$	$1\frac{17}{32}$	$1\frac{15}{64}$	$\frac{15}{16}$	$\frac{11}{16}$	$\frac{15}{32}$
19.	302.9	$4\frac{29}{64}$	$3\frac{57}{64}$	$3\frac{23}{64}$	$2\frac{55}{64}$	$2\frac{13}{32}$	$1\frac{63}{64}$	$1\frac{39}{64}$	$1\frac{19}{64}$	$\frac{63}{64}$	$\frac{47}{64}$	$\frac{31}{64}$
20.	287.9	$4\frac{45}{64}$	$4\frac{3}{32}$	$3\frac{35}{64}$	3	$2\frac{35}{64}$	$2\frac{3}{32}$	$1\frac{11}{16}$	$1\frac{3}{8}$	$1\frac{3}{64}$	$\frac{51}{64}$	$\frac{17}{32}$

flat car wheels. The fact is that rails are made for heavy duty, and drop tests under sudden blow from a hammer weighing a ton are required of full-size rail specimens to show that the metal will bend before it will break. It being known that rails take permanent set under the gag and that the stock rails of split switches are bent cold, and yet are considered safe, why should the blows from a sledge hammer in curving be regarded severe treatment? The fact that the lever-and-sledge treatment, properly administered, curves the rail uniformly its whole length, and without kinking it, proves that the blows received are only moderate; if they were otherwise the rail would be bent most sharply at the points where it was struck. If any man has seen rails break while being curved in this manner he should regard such incidents in the light of fortunate discoveries, for it is quite evident that the rails were unfit for service in the track. Rails cannot be curved satisfactorily with a jim-crow. This tool is intended for bending rails to an angle, but not to a curve. Any attempt to employ a jim-crow in rail curving will result in very slow progress and a series of angular bends in lieu of a curve.

Table IV. gives middle ordinates for rails 10 to 30 ft. long, to the nearest 64th of an inch. It is not necessary to be so exact as this in curving rails. It is sufficiently close to work to the nearest ¼ in. or even to the nearest ½ in., for heavy curvature. It will be noticed that the middle ordinate of a curved 30-ft. rail is approximately ¼ in. multiplied by the degree of curve. This rule is sufficiently exact for any work of rail curving, and may be used in preference to consulting the table, and also for curves of higher degree than are provided for in the table. The middle ordinate of a curved 33-ft. rail, which is now the standard length on a number of roads, is (nearly enough) $^3/_{10}$ in. multiplied by the degree of the curvature.

Handling Curved Rails.—In handling curved rails it is well to so arrange the work that the rails may be taken from the curving blocks or machine and loaded directly onto the cars; otherwise the expense of handling is considerably increased. After rails are curved they should be handled with special care and should not be thrown.

In laying track where curves are numerous the rails should be curved in the material yard or before they are shipped to the front. A man from the engineering department is usually given charge and supplied with a note book giving the location and lengths of the tangents and curves of the line. This man has charge of loading the rails and the ties (in case the ties are of different kinds, so that a harder quality may be had for the curves) and he is supposed to so arrange the shipments that cars loaded with material for the curves are forwarded in their proper order. By a little calculation the cars can be arranged to come exactly in the order needed. To avoid confusion, cars loaded with rails for certain curves should be labeled by marking, on a shingle or card tacked to the side of the car, the station numbers of the P. C.'s between which the material is to be used. In building the Columbia & Western branch of the Canadian Pacific Ry. each car was marked with the initial station for any curved rails carried, and the first and last rails of each curve had the station number painted on them. Rails curved for different degrees of curvature should not be mixed, or carelessly loaded on the same car. To avoid inconvenience the curved rails for different curves should be placed in separate piles, divided, if necessary, by pieces of board. It is also customary in loading curved rails not to place rails for more than one curve on the same car, the balance of the car-load, if there is room to spare, being finished out with straight rails.

On the question of curving rails for spiral or easement curves it would of course not be expected to curve them for that portion of the easement the curvature of which does not exceed the limit governing the curving of rails in the usual practice of the road. From information published in the committee report on "Track," to the American Railway Engineering and Maintenance of Way Association, in 1901, it appears that a number of maintenance-of-way men prefer to curve the rails of the spiral to correspond to the curvature of the spiral at the position of the rail; that is, that each rail should be curved to that middle ordinate which will fit the degree of curve at the point where the middle of the rail lies when in position on the spiral. As already seen, however, there is no necessity for any great precision in rail curving as, if the rails are curved within 2 or 3 deg. of the stated curvature, they will not be subjected to appreciable strain when spiked to that curvature. In all ordinary cases it would seem sufficient for practice to follow a method suggested by Mr. Jerry Sullivan, which would be to use on one side of the easement the rails curved for the regular curve, with straight rails on the other side. By way of illustration, for an easement at the end of a 6-deg. curve, the rails curved to 6 deg. might be used as far out on the easement as the point where the curvature decreases to 3 deg., with straight rails on the inside of the curve to offset the strain due to the excessive curvature of the rails on the outside. This method would obviate the necessity for curving rails to different ordinates for the same curve, where spirals or easement curves occur, and undoubtedly answer just as well as if every rail was curved for the position in which it lies on the spiral.

25. Allowance for Expansion.—For every degree, Fahrenheit, change in temperature steel is supposed to change its dimensions about .0000065 of itself, or about 1 part in 150,000, the change varying slightly according to the chemical composition of the metal. As steel rails are subject to the extremes of atmospheric temperature allowance must be made for the resulting change in length, according to the temperature of the rail at the time of laying it. The correspondence of the temperatures of the rail and the atmosphere does not seem to have been thoroughly investigated. It is commonly understood, however, that the rail comes to the same temperature as the atmosphere except, perhaps, while the sun is shining, when it may become hotter. In that case it is considered good practice to take the temperature by holding the thermometer against the rail, on the shady side. On the other hand the ground is supposed to have some considerable effect on the rail temperature, by way of radiation, usually in the nature of a compromise of both extremes, but it remains to be demonstrated whether this effect is reasonably constant for such conditions as have to be taken into account. Temperature tests on 100-lb. rails in the track, by Mr. P. H. Dudley, by means of a "companion" rail with a hole drilled in the head for the insertion of a thermometer, showed that when the thermometer registered 135 deg. F. in the sun the highest temperature obtained in the head of the rail was 120 deg. F. and the base of the rail, as a rule, was 2 to 4 deg. cooler. At the other extreme, careful observations taken by the late Mr. A. Torrey, chief engineer of the Michigan Central R. R., showed that between 20 deg. F. and —20 deg. F., or over a range of 40 deg. of temperature, the length of rails was unchangeable. Changes of temperature between these limits produced no movement, but above 20 deg. F. the rail was quite sensitive to temperature changes. The rail on which the observations were made was 500 ft. long, built up by rigidly splicing 30-ft. lengths together as one. Further details are given under the subject "Longer Rails," § 172, Chap. XI.

Such observations are not reconcilable with the customary basis for computing allowance for expansion, which assumes a uniform change of length throughout the whole range of temperature. Unfortunately, observations of the kind noted have been too few to cover conditions in general, and so practice abides by the safe side, providing for the full effect of atmospheric temperature within the extremes registered by the thermometer. Carelessness in not properly allowing for change of temperature usually results in harm from the expansion of the rails in hot weather, and frequently as much from contraction during cold weather. To make no more provision for change of length in a long steel bridge than is sometimes made for track rails would soon result in trouble either for the bridge or the coping of the abutments.

It is safe to assume that there are but few localities where a rail will change in temperature, between the extremes of winter and summer, more than 180 deg. F., which corresponds to a change in length of $^7/_{16}$ in. for a 30-ft. rail, or a change of $^1/_{16}$ in. in length for each 25 deg. change of temperature. As the extremes of temperature in different localities may vary widely it is not feasible to arrange a table of expansion allowances suitable for universal application. In the northern part of the Mississippi valley the extremes are something like —40 deg. and + 140 deg. F. in the sun, while in parts of Arizona they would be more like + 20 and + 150 deg. F. in the sun. In a general way, however, it might be said that for most places in this country the range of temperature between coldest in winter and hottest in summer (in the sun) is about 150 deg. F. This change in temperature would produce about $\frac{3}{8}$ in. variation in the length of a 30-ft. rail. In some parts of the coast of California the variation between extremes is probably not more than 60 deg. F., thus requiring but little more than $\frac{1}{8}$ in. for change of length in a 30-ft. rail. It is highly desirable that no more space than is really necessary be left at the rail joints, and in localities where the extremes do not vary widely but little allowance need be made. A general rule for expansion allowance in laying 30-ft. rails, at any temperature, at any place then would be: Ascertain the lowest temperature to which the region is subject, and also the highest, in the sun, and take the difference in degrees, Fahrenheit. Divide this difference by 25 and multiply by $^1/_{16}$; this will be the opening in inches when laying at the lowest temperature. Then to find the opening to be allowed when laying at any other temperature, decrease from the opening for the lowest temperature at the rate of $^1/_{16}$ in. for each 25 deg. above the lowest temperature. For rails of length other than 30 ft. the allowance will be in proportion.

Results calculable by this rule will show that the spaces to be allowed for rail expansion when laying at the same temperature in different localities may vary considerably; and not only according to differences in the total variation of temperature of the different localities, but also because of wide variations which may exist between the lowest temperatures in the different localities. Thus, for illustration, suppose the total variation of temperature, between winter and summer, at each of two places is 150 deg. F. The expansion allowance for the lowest temperature will then be the same ($\frac{3}{8}$ in.) for both places. But suppose that the lowest temperature for one locality is —40 deg., while for the other it is zero. The difference in the expansion allowances for the two localities when laying rails at the same temperature in both, will then always be $^{40}/_{25} \times {}^1/_{16}$ in. $= {}^1/_{10}$ in., which is a matter worth considering. At some high altitudes, for instance, the thermometer may never register higher than 80 deg. in the sun, and rails laid in such places at that temperature should be butted end to end, because then the only movement to occur will be in the way of contraction. At some lower altitude, perhaps not a great distance away, rails laid at the same temperature may easily require a full $\frac{1}{8}$-in. space interval for expansion. It is thus seen that instances frequently arise when specific rules for rail expansion openings should not be followed.

The foregoing statements refer to the space necessary to permit rails to expand freely. Where the ballast is scarce or the rails of light section it is not considered safe to skimp the expansion openings, but late years, with heavy rails, on track well filled in, some roads have made it a practice to retain part of the expansion in the metal itself. The vindication of this practice is that heavy rails are stronger, considered as a column, and therefore better able to undergo compression without buckling than are rails of light section. It is the practice with a number of roads using rails as heavy as 85 lbs. per yd. (and possibly in some cases where the rails are lighter) to reduce the expansion allowance to one half the space required for free movement at the highest temperature. In long tunnels, where the temperature remains about constant, no allowance for expansion is needed and hence in laying rails therein they should be butted end to end. In laying rails across a sag which is later to be raised to grade it is necessary, in order to avoid cutting rails, to allow extra space at the joints to provide for the shortening of the track when it is lifted to the proper level.

A convenient form of expansion shim can be made out of narrow band iron by bending over one end at a right angle, so that it will hang in place over the end of the rail. As a matter of convenience there should be an assortment of three sizes or thicknesses—some $^1/_{16}$ in., some $\frac{1}{8}$ in. and some $\frac{1}{4}$ in. thick. If a single shim of one of these sizes does not suffice for the opening, two or more may be combined and used together. It is well to have the thickness plainly stamped on the shim. The expansion shims of the Southern Pacific road are of six different thicknesses, beginning at nothing (tight joint) for temperatures between 130 and 150 deg. Fahr. and increasing in multiples of $^3/_{64}$ in. for each 20 deg. decrease down to 50 to 70 deg., at which the thickness is $^3/_{16}$ in.; for 32 to 50 deg. the thickness is $^7/_{32}$ in., and for 0 to 32 deg. it is $\frac{1}{4}$ in. These shims are of iron, and the temperatures at which it is supposed they are to be laid are marked on the shims. For example, shims for use in temperatures anywhere between 70 and 90 deg. are marked "70-90." On its lines south of the Ohio river the Illinois Central R. R. uses but three thicknesses—$^1/_{16}$ in. for the very hottest weather, $\frac{1}{8}$ in. for spring or fall and $^3/_{16}$ in. for cold weather. On its northern and western lines a $\frac{1}{4}$-in. shim is used for the very coldest weather. An assortment of wire nails of different sizes make convenient shims, and such are sometimes used. Another form of expansion shim much used is a small star-shaped malleable casting with four legs radiating from the center at right angles. The legs vary in thickness to suit variations in temperature, usually from $^1/_{16}$ to $\frac{1}{4}$ in. This device is known as a "grasshopper" or "spider" shim.

The use of wooden expansion shims is not considered good practice, because they get squeezed when the rail is set back hard, and leave the opening smaller than it is intended to be; and besides, it then becomes difficult for the splice men to get them out. The rules of the Northern Pacific Ry. require iron shims for ordinary work, but to prevent the rails from being shoved back when laying track on steep grades sawed wooden shims are used and left in place until the track is fully spiked and bolted. Lath have been used a good deal for shims, the free end being easily broken off each time from the piece held between the rail ends. To mention still another method, expansion has been provided for in the following manner: A piece of wood about ½ in. thick is placed between the rails temporarily when they are set together, thus leaving the space too wide. The head strappers keep well up to the rail car, and each carries a steel shim of oval form about ⅜ in. thick in the middle, tapering off to about ⅛ in. in thickness at each end. By inserting this shim in the joint and putting the wrench handle through a bolt hole the rail is pulled back against the shim to make any desired opening, depending on how far the shim is shoved into the joint.

Shims, assorted as to the various sizes, should be carried in pails or boxes hanging at or attached to the head end of the rail car, on either side, where they can be reached by the heeler. They are collected after being used each time,and so answer their purpose over and over. In cases where shims of the thinner sizes are not at hand the proper joint spaces may be provided by an averaging process, using a shim of excessive thickness at part of the joints and laying the other joints tight. Thus, for example, a ⅛-in. shim laid at every other joint would serve the purpose of $^1/_{16}$ in. shims at every joint. Of course such is not the most desirable manner of distributing the expansion allowance, but, in the light of conditions widely existing, it is not after all so very objectionable. An ever-recurring trouble with expansion space is that it will not remain evenly distributed, howsoever carefully it is arranged at the start. The tendency of the rails under traffic is to bunch together at some points and pull apart at others, leaving abnormally wide openings. A familiar illustration of an extreme case of this action is the behavior of the rails on lines of frequently opposing gradients, where the rails run together, closing the joints in the sags, and pull widely open across the summits. This behavior would seem to be a good argument why the expansion allowance should not be permitted to exceed the least space consistent with safety.

Another difficulty frequently experienced in the way of maintaining the desired expansion allowance is the bodily movement of long stretches of track while it is being laid. Such a movement is most liable to take place when track-laying is carried on during the early spring or late fall. For an hour or two after work begins on a frosty morning the temperature of the rail may be at freezing or below, but by noon it may run up to 80 or 90 deg. in the sun. As the splices are tightly bolted and the ties less resistant than on ballasted track, a considerable stretch of newly-laid rails may expand without rendering in the splices and the same openings then exist that were provided for a temperature perhaps 50 deg. lower. Before the temperature falls a long piece of track may be laid which will hold the piece laid in the morning from pulling back, and thus the joints for some distance may permanently remain too open. Some trackmen when laying track under the temperature conditions noted attempt to make allowance for the movements described by decreasing the expansion allowance, but it is, after all, a difficult matter to regulate.

In allowing expansion space between rails with miter-cut ends the measurement should obviously be made in line with the rail, which is askew to the opening; and the thickness of the shim should be less than this measurement, and in the ratio of the cosine of the angle of the miter. For instance, if the rail ends are cut off to an angle of 45 deg. the thickness of the shim should be 0.7 of the expansion allowance. In using expansion shims in such joints the precaution should be taken to have the rail ends exactly in line as they are moved up to the shim, or when the space is measured, else when they are lined up by the splice bars the space allowed will either close up or open out, and thus be correspondingly narrower or wider than the intended allowance.

26. Splicing.—Following next behind the rail-laying car come the splicers or "strappers," as they are commonly called. These men are usually divided into two parties—the "head strappers," who should be quick and steady with the fingers, to put on the splices and one bolt in each splice to hold it in place, and the "back strappers," who put in the remaining bolts and finish tightening the splice. The act of putting on a splice quickly is worth some attention, because some men, apparently, never learn how to do it. It is not so much dependent upon rapidity of movement as upon having an eye to adjustment and a firm, steady manner of doing things. The first thing to be done is to get the ends of the two rails in line, at the same level, and take out the expansion shim. This the head strapper does by prying on the rail with his wrench in one hand, and grabbing up with the other hand a chip, pebble or some other object to put under one of the rails to hold it up even with the other; it then takes but an instant to put the ends in line. Then, standing inside the rail, if the bolt heads come on that side, he puts the splice bars in place, not by feeling for a bolt hole in the rail with his finger, but by sighting down with the eye—a more rapid method. He then puts a bolt through one of the middle holes, gives the nut a few turns with the fingers or wrench, far enough to hold the splice in place, and goes ahead to another joint. The head strapper should work some little distance in rear of the rail laying, as, if he gets too near, the removal of the expansion shims may permit the rails to be bunted back and close the joint openings.

The back strapper next comes along, puts in the full number of bolts and tightens them. He should stand so as to use his wrench across the rail; or, since it is hard work, he may rest himself occasionally by sitting down on the rail and tightening the nuts by pulling (not pushing) on the wrench. A man skillful at catching a nut with a wrench need not lose much time by sitting down at his work occasionally. He should carry a spike maul and, after the bolts are fairly well tightened, sledge the splice bars together by striking each a hard blow between every two bolt holes and at the ends; and each bolt head should be lightly tapped. This hammering will pulverize the oxide scale between the surface of the rail and the splice bars and drive the splice bars to a closer fit. The bolts will be found loose after this hammering and should then be tightened again about as tight as a man can conveniently pull on them with an 18-in. wrench, using both hands and standing on his feet. Such an adjustment will not be too tight, as it would if the splices were worn to a closer fit with the rail, as is the case after trains have run for awhile. Nuts should be put on flat side to the washer or nut lock, and before they are tightened the splice bars should be adjusted to bring the bolts squarely across the rail. A good fit for the bolt head cannot be obtained unless the bolt is at right angles to the splice. After the track is ballasted and lined the bolts should be thoroughly gone over again, for after surface kinks have been taken out and the rails put in line some of the splices will be found to have loosened. Some roads require that within a month after traffic begins running the bolts shall be tightened again.

In the days when rails were of light section it was necessary, in order to keep the nuts out of the way of the wheel flanges, to put the bolts through the splice from the inside. As rails increased in hight such interference became no longer possible and the practice of placing the nuts on the gage side of the rails is now quite extensively in vogue.

A supposed advantage sought by this arrangement is to place the nuts where they are most readily caught by the eye of the track-walker, for on large steel they are not easily seen over the edge of the rail by one walking inside the track. So far as concerns the track-walker's convenience, however, the advantage lies rather with the old way, or with the practice of placing the nut on the outside. A track-walker locates a loose bolt, not by looking at the nut, but by the appearance of the bolt head, there being always a ring or streak of rust on the splice bar around the head of every bolt the least bit loose; with a bolt kept tight such is not the case. Where the nuts come inside it is not so convenient for the track-walker to tighten loose bolts as it is where they come outside, for in the former case he will step outside the rail to tighten the nut and in the latter he will simply reach over the rail while standing in the track, give the nut a few turns and walk on. It is sometimes claimed that derailed wheels are not so liable to cut the nuts from the gage side as from the outside of the rail, but the only security to be had in this respect is by placing part of the bolts one way and part the other way, so as to have nuts on both sides of the rail. This arrangement will prevent a derailed wheel or car truck from shearing all of the nuts, thus insuring that there will be bolts to hold each splice in case of accident. The importance of this precaution is well understood, for it has happened many a time that a derailed freight car truck has been hauled several miles over the ties, stripping all the nuts from the joint splices on one side of the track, to the peril of following trains, or even to following cars in the same train. With such danger in prospect it is now quite largely the practice to reverse the position of alternate bolts in joint splices, thus bringing half the nuts on each side of the rail. In some cases the two middle bolts in each splice are placed to bring the nuts on the opposite side of the rail from the remainder. Some trackmen profess to believe that the scheme of putting bolts both ways through the splices affords a tighter adjustment of the splice bars to the rails, and it is pretty well agreed that it does not permit the joint to pull so widely open when the rails contract in cold weather, and that it disposes the bolts in a manner to oppose the contraction of the rails with less liability of being broken. When this arrangement is in contemplation for bolts to be held from turning by a shank of square or oval section, the punching of the splice bars must be arranged to correspond. In some cases both splice bars are punched with oval holes throughout. The practice with the Pittsburg & Lake Erie and the Michigan Central roads is to punch the holes in both bars alternately round and oval, but relatively reversed in the two bars of each pair. In doing this the spike slots can be located to dodge the nuts of the bolts. It should also be borne in mind that the presence of nuts on the gage side of the rails may have some bearing on the design of snow flangers.

Where rails of different hights come together in main track the splice bars should be stepped and made to fit accurately, and it is sometimes found necessary to offset them to suit a difference of thickness in the two webs or a jog in the alignment of the same. The joint in this case should be made supported and an iron shim should be put under the rail of lesser hight, or a stepped shim under both, to bring the top surfaces of the rail heads even. This shim should be spiked to the tie, like a tie plate, so that it will remain in place. A splice made to fit two rails of dissimilar section is generally known as a "compromise" or "offset" splice, and some of the affairs turned out at blacksmith shops by working over common angle bars are badly crippled, in one way or another, usually by heating and pounding until the section of the bars is much reduced, and also by forming a square shoulder at the jog (See §95 and §212).

27. Spiking.—Spiking is one of the most important details of track-laying, because it is very troublesome to remedy when wrongly done. Spikers should not be pushed, for if they are they will surely slight the work in some respect. Two men drive spikes together, delivering blows on opposite sides of the rail at alternate intervals. Right-handed men should be paired with right handed men, and left-handed men with left-handed. Frequently right and left-handed men are paired together, principally because it looks better, perhaps, to see both facing the front; but there is nothing gained in rapidity thereby and the work cannot be done so satisfactorily. While driving a spike the spiker invariably pulls or starts the tie toward himself at each blow. It is clear, therefore, that two men driving from the same side of the tie will both move it, unless it can be held up more tightly than can always be easily done, and both will tend to move it in the same direction; but when they stand facing each other the tendency to pull or start the tie one way is balanced by a like tendency from the opposite direction, and the tie is not moved in being spiked. Spikers usually stand beside the rail while driving spikes, but a good spiker can drive well while standing in almost any convenient position. A poor spiker, like almost any other poor workman, will make a good many movements on his feet which a good spiker would not; such, for instance, as stepping astride the rail or measuring his steps when about to begin driving. It is a poor spiker who will go about the work with as much deliberation as when aiming a gun. Some men train themselves to spike equally well either right or left-handed, and it is a good habit to get into, not only because it enables one to handle himself more adroitly at the work, but because the man who can change hands with a tool occasionally will become less fatigued at using it, and after years of work of this kind he is not so liable to get that "hump" on one shoulder, so commonly seen with trackmen.

The line side of the track is of course spiked first. To begin with, the spiker on the outside sees that the tie end is at proper distance from the rail, driving it through when too long, or having his partner drive it from his end when too short; he then sets his spike. When a gage mark is not placed on the tie face he measures by a notch cut on his hammer handle. This length should be such that a tie of standard length projects equally beyond both rails when they are spiked to proper gage. When the rail is too far out of gage with most of the tie ends the man holding up the ties, called the "nipper," should take his bar and throw the rail over to approximate gage. After the spike on the outside of the rail has been set, so as not to allow the tie to shove through while it is being raised to the rail, the nipper holds it firmly up against the rail base while the spikers do the rest. Before the spikes are driven, however, the men should see that the tie is properly spaced from the others and square across the track. If this is not attended to the spikes will be out of true when the tie is shifted to proper position.

The nipper is usually provided with a pinch bar (a crow bar is a poor tool for this purpose) and a block of wood about 2x4x12 ins. in size, for a fulcrum, with a spike driven into it for a handle, and ordinarily they answer the purpose well enough. In narrow cuts, however, and in other places where special conditions prevail—as, for instance, when laying street railway track in a trench excavated but little wider than the length of the tie—the lack of room on the shoulder at the end of the tie will not permit a bar to be used at that point. In such a case either two bars—one each side of the tie—or a special contrivance must be used to hold the tie up to the rail. Two or three devices for this purpose operate on the principle of holding the tie to the rail by prying over the latter. The Sterlingworth holding-up bar (Fig. 33) is a device of this kind. It is a long, heavy bar, forked at one end and provided with hooks which engage the tie in the middle of the under face. The fork of the bar is placed astride the rail, as seen in the figure, which also shows the inclination of the bar when holding the tie in position for driving the spike.

Spikes should not be leaned to suit the swing of the spiker's hammer, but should be driven perpendicular to the tie face. It requires some vigilance to get men to abide by this rule, since one must bend his back a little in order to do so, but it must be insisted upon. Where a spike has been driven slantwise it is a difficult matter to catch the head with a claw bar when the spike must be pulled, and if the spike is inclined under the rail the latter will ride the neck of the spike and cut it. One aid to good spiking is to have the hammer handles the full regulation length of 3 ft. Ordinarily men will not drive spikes properly unless they are watched and criticised occasionally; let foremen not forget this. The spike should be started plumb, with the side of the point against the rail flange, so that it will crowd the rail all its way down. The finishing blow should tap the head down to a firm hold upon the rail flange, but not too forcibly, lest the spike be broken off or cracked under the head or the neck of the spike be forced away from the rail flange. The effect of this last blow is to spring the rail base slightly into the fibers of the wood and start the spike farther into the tie, so that the spikes are made to hold the rail base to the tie with a force of several hundred pounds. This drawing force is caused by the action of the wood fibers, which are forced inward with the spike and act somewhat like a pawl to resist any tendency to pull the spike back.

The usual practice is to drive two spikes in each tie for each rail, and to drive them staggered; that is, on opposite sides of the same rail the two spikes stand near opposite edges of the tie face. In ties sawed or hewn on four faces spikes should not be driven nearer than 2½ ins. to

Fig. 33.—Sterlingworth Holding-Up Bar.

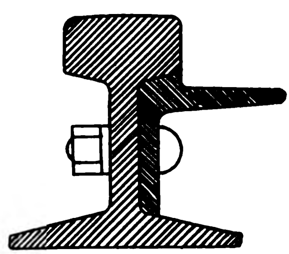


Fig. 40.

the edge of the tie face and in pole ties they should be driven at about ¼ the width of face from the edge of the face. Spikes should be so driven that they have no tendency to swing the tie askew to the rails before the track is ballasted. This requirement can be fulfilled by driving both outside spikes near the same edge of the tie face and both inside spikes near the other edge of the face. For the same reason spikes should not be driven in the middle of the tie face; besides, with pole ties, the heart of the timber being under the middle of the face, the spike does not hold so firmly when driven there and it is also more liable to split the tie or to come where the tie most usually checks open. Spikes should be driven to "cross bind," the purpose of which arrangement is to clutch the rail and resist creeping, as explained more fully and by diagram in § 103, Chap. VII. The advisability of driving spikes in the slots of splice bars is taken up in the same connection. On curves the outside spike on shoulder ties should be driven on the edge of the tie nearest the joint, as the nearer it stands to the joint the better is the assistance it can render in holding the joint to gage. The best plan, however, is to double spike the ties on the outside of the outer rail on all curves. The cost of the extra spikes is but a comparatively small item, and the rail is so much more firmly supported that the use of rail braces or tie plates may be unnecessary, where in many cases with single spiking they might be needed. This matter is referred to again under the subject "Rail Braces," § 49, Chap. V. When spiking ties in this manner the spiker standing inside the track should strike across the rail and help his partner down with the extra spike.

On the gage side of the track every third tie at the farthest, that is, at least one-third of the ties, should be spiked to the gage; but where the ties lie very unevenly, and on curves of short radius, the rail should be spiked to the gage on alternate ties. It is more important that men spiking with the gage should be experienced and skillful in driving spikes than it is with spikers on the line side. The nipper for the gage spikers should keep the rail thrown nearly to the gage ahead of them. If the line side is left badly out of line after being spiked it is well to throw it into fair line before spiking the gage side. Where the tie that is being spiked is held up firmly the rail can be moved slightly to gage by a stroke sidewise with the hammer; if not, or if it be moved slightly out of gage after the spikes have been started, but before they are down, it can be drawn powerfully by slightly bending over the spike on the side from which the rail is to be moved, and as the spike is driven further down it will crowd the rail over. There are those who object to such bending of the spike to crowd the rail while driving; but if it be done by one who knows how and who can handle a hammer properly it is the quickest and most practicable way, and no harm need be done. It saves time in getting the rail to good gage and an experienced trackman would think of no other way. In order that the spike may crowd or "draw" with most force when driven in this manner it should be started perpendicularly to the tie face, the same as when driving a spike under ordinary conditions, and not slantwise under the rail, as some wrongly suppose; then it should not be bent over until after half way down, since the body of the spike is then firmly held in the tie and, by bending the spike and driving straight down upon it, a powerful side pressure is exerted against the rail. In curves of short radius a sharply pointed pick is the best tool for crowding and holding the rail to gage. If the gage is tight the inside spiker starts his spike first, and if it is loose the outside spiker starts his spike first, and the first spike started should put the rail to gage before the other spike is started. Then if there be no tendency in the rail to spring itself out of gage both spikes should be put down together; otherwise the advantage should be given the spike first started. But if a slight bending inward of this spike will not bring the proper gage the rail should be moved by sticking a pick into the face of the tie ahead and prying it over. The gage should rest squarely across the rail just far enough in advance of the tie which is being spiked to be out of the way of the hammer of the inside spiker, and it should be kept there until the tie is spiked. The men who do the gaging cannot spike as rapidly as the other spikers and, where the ties are so soft that a spike can be put down with not more than three hammer blows, one spiker is enough to go with the gage; for where under such circumstances there are two, one will be standing still doing nothing a large part of the time; and so, to economize time, he might better form part of another spiking crew.

Rails should be gaged to within almost a hair's breadth, because it can just as well be done that way after men become a little expert. Of course there is no real necessity for such close work except in its moral effect, for if any looseness is allowed in this respect there is no telling where it will end. The gage should just come to place on being raised 3 or 4 ins. at one end and let drop; if there can be any movement of it across the track it is too loose; if it will not drop to place it is too tight. The gages should all be tested and closely inspected by the foreman every morning, without fail. There is more necessity for watching gages on track-laying than in track repair work, for irresponsible men will sometimes permit the rail to spring inward on the gage with such force that one of its lugs is loosened, and say nothing about it. It is the duty of the men spiking the gage side to see that all ties spiked are put square with the rails, and also to spike no tie having a warped or twisted face until it has been adzed to fit evenly with the rail base on that side. Of course it is taken for granted that when spiking the line side both edges of each tie face have been brought up evenly to the rail base on that side. Sometimes the necessity for adzing does not appear until after one end of the tie has been spiked.

In order to make haste, sometimes, when the crew is short-handed, only the joint, center and quarter ties are spiked before the outfit train is let over them; but it is better not to do this, because where there are so few spikes holding, on rails which have not as yet been brought to line and surface, there is, at best, liability of spreading slightly the gage, thus making it necessary to regage the rails before the remaining spikes are driven, if good work is to be done. It is cheaper in the end to go slower, spike all the ties as the work progresses, and do everything well. The expense of regaging new track disturbed in the manner noted will usually be found to exceed any saving that can be effected by skipping part of the work temporarily and leaving the rest to be done at some time later, especially if the first work done is liable to be injured in the meantime. Foremen should bear in mind that the tendency of things in track-laying is usually toward loose methods, and that they must constantly look out for careless work and correct it as occasion requires. Possibly it may seem to the casual observer that much has been said in the foregoing about a matter of little consequence, as spiking might at first appear to be, but experienced trackmen well know that there are men who, if not taught, would not learn to spike properly in 40 years.

In the present connection mention may be made of a machine for driving spikes in track-laying that has been used on the Detroit United

Ry. There is a low four-wheel truck, the frame of which is suspended below the axles, and this truck carries an upright boiler and two steam hammers, the latter being located to stand in position over the two rails. Opposite each hammer there is a pair of tongs used for picking up the tie and holding it firmly up to the rail as it is being spiked. These tongs are operated by a rock shaft extending across the tops of the cylinders of the steam hammers, and the leverage is such that the tie is held up against the rail with a pressure of four tons. Each hammer drives two spikes at one time, and the force applied is such that spikes in cedar ties are driven with two blows. The rail is held to gage by a cross bar in front of the machine, engaging the rails by means of rollers at the ends, and unless the gage is exact the hammers will not hit the spikes. The machine is operated by two men, and it will spike about a half mile of track per day. It was designed by Mr. J. Kerwin, superintendent of tracks for the road named, and is illustrated in the Railway and Engineering Review of May 17, 1902.

28. The Track-Laying Crew.—Since much depends upon the skill which men acquire while engaged in the different kinds of work in track-laying, it is well to endeavor to get men who will remain while the work lasts. Almost all of the work requires lively men, to expedite the work, of course, but more especially because there is much to be done where two or more men must work together, and each at intervals which begin only after some other has made ready; that is, in many cases one man must "wait on another man's motion." Take, for instance, two spikers at work, with a nipper. Each spiker must wait while the other starts his spike, and both spikers must wait for the nipper to hold up the tie. After the spike is driven all three must take a step or two to the next tie ahead. So it is that a large portion of the time is consumed in getting ready and only a comparatively small portion at putting down the spikes; and thus it necessarily goes throughout all the work. But men who are slow of motion, unsteady of movement, or lazy, always "get ready" with deliberation; and here is where much time can be killed and not be so easily seen, except as results will show. There is but little use for lazy men or men of slow motion around track-laying, even at any price. Men who are lively, steady and intelligent will do much more work than men not so qualified, and do it better, without hurry, worry, fatigue or grumbling.

Men working with the rails, commonly called "the iron men"—splicers, spikers and rail-car men—are usually paid about one-third more wages than the men who handle the ties. It is well to so grade the work, since it has a tendency to make each man feel some responsibility in his position. Men who work with the rail car, including the foreman, should all be able to speak the same language, and they should be strong, active men; no old or infirm men should be put at handling rails; and it is a place where awkward men of any age are liable to get hurt. Spikers should be reliable men, able to swing a hammer freely; muscle-bound men can never spike well. Strappers should be quick and steady, although it is not necessary that rapid movements should be constantly kept up. It is a great mistake to think that almost any kind of a man will do for "nipping" or holding up ties. If there is any tool a slovenly man will handle awkwardly it is a bar; while for a lazy man a job at sitting on a bar holding up ties is a "picnic." The nipper should be an active man. Instead of standing and watching the spiker start his spike he should be getting his block and bar in position to raise the tie promptly when the time comes. He should also know enough intuitively about the laws of the lever to fix a fulcrum properly for his bar, so as to get a good purchase. Reliable, industrious boys can do this work. Old or infirm men do well at distributing spikes and bolts, collecting expansion shims, carrying water, etc. Men not active at handling tools can work on the ties better than anywhere else, but lazy men should be discharged. The two or more men who line and space the ties should be paid the same wages as the iron men, because they are engaged in work which must be relied upon.

In regard to the length of track a given number of men can lay in a day it is difficult to give definite estimates, since so much depends upon local conditions and the circumstances. The opportunity for distributing the ties cuts the most variable figure in the cost of labor in track-laying. The weight of the ties and their quality, as to whether hard or soft; the weight of the rails, and manner of laying them (square or broken joints); the condition of the roadbed with respect to grades, curves, open culverts, etc.; the intelligence of the foremen and the control they have over the men, as well as the general intelligence and willingness of the men; the success of the system of forwarding materials from the base of supplies; and a score of other things—all determine very largely the number of men required to lay any certain length of track per day.

Where the ties are hauled ahead with teams, 56 laborers, three foremen and 11 teams ought to lay a mile of track in 10 hours, under average conditions, without hurrying. The men would be divided up about as follows:

4 men loading tie wagons.
10 teamsters and 10 teams haul. ties.
6 men placing, lining and spacing ties.
8 men unloading and placing rails*.
2 head strappers.
4 back strappers.
12 spikers.
6 nippers.
1 man distributing spikes.
1 distrib. bolts and collect. expan. shims.
1 water boy.
1 teamster, 1 team haul. rail car.

56 men, total laborers.

*These men unload the rails from the supply train, load the rail car and lay the rails to place on the ties.

Where the ties are run out on rail cars and carried ahead—one man carrying a tie—64 laborers, three foremen and two teams ought to lay a mile of track in 10 hours, under average conditions, without hurrying. This arrangement allows 21 men to unload ties from cars, load them upon the rail car, and carry ahead and drop them upon the grade. Circumstances might so require that to keep things moving smoothly a slight change would be made from the arrangement given and the men changed around to some extent; as, for instance, should the tie men get behind in their work the rail car men could give them a hand; or if the force at splicing and spiking be not able to keep up, the rail men could be shifted for awhile to assist them. It is practicable to get enough men together to lay four or more miles of track per day of 10 hours; but, all things considered, where time is not the most important element, it probably costs least per mile to lay about 1½ miles per day, providing all conditions are most favorable.

Two men working together can lay to place, line and space about ⅓ mile of ties per day of 10 hours. One man can put on and bolt up about 60 four-bolt splices in a day. Two men and a nipper ought to spike about 1100 ft. of track in soft ties, or 750 ft. of track in hard ties, in a day. Eight men can unload from supply train, load on rail car, unload and lay to place enough 30-ft. average-weight rails for a mile of track per day; where they do not go back to load they can unload from a rail car and lay to place 2 miles per day. This latter arrangement would require a crew part of the time to load; the rest of the time they could be put at handling ties. Two rail cars would be needed. The rail car should always be hauled with the team, whether loaded or empty, unless when going one way it should be down grade sufficiently for the car to run itself. To lay to place the rails for 3 miles of track per day requires two sets, or about 15 men, unloading from both sides of the rail car at the same time. One crew, large enough to pick up and carry the rails easily, could attend to the loading of the rail cars. The outfit train would have to be kept close up to the work. To expedite the work it is sometimes the practice to lay only half of the ties ahead of the supply train. As the train moves along the remaining ties are thrown off about where they are needed and a gang working in rear of the train places them in the track and completes the spiking.

Track-Laying Records.—In order to show what has been done in the way of rapid track-laying some official records of work on the Great Northern Ry. will be given. The materials were distributed with teams and rail cars just ahead of the train, and the work throughout was done in the ordinary way. Between Minot, N. D., and Great Falls, Mont., during the month of August, 1887, an average of 4.27 miles of track was laid per day of 10 hours. The force was distributed as follows:

Unload rails and load iron cars....	24	Marking and adjusting joint ties...	4
Rail car gang	13	Lining ties	2
Spikers	32	Hauling ties ......65 teams, men	65
Nippers	16	Distributing spikes	2
Strappers	10	Lining track behind	8
Loading ties	26	Hauling rails ......6 horses, men	3
Distributing ties	8		
Spacing ties	4	Total men.....................	217

Six rail cars were used, and as soon as each car was unloaded at the front it was run back behind the spikers and taken off the track. When the last of the six cars had been unloaded the other five were again placed upon the track and the supply train moved ahead. The best record made was 8.01 miles of track laid in 11½ hours, the force being distributed as follows:

Hauling ties ......75 teams, men	75	Spikers	38
Loading ties	28	Nippers	19
Distributing ties	10	Strappers	12
Spacing ties	4	Distributing spikes	2
Lining ties	2	Lining track	8
Marking and placing joint ties....	4	Hauling rails ....6 horses, men	3
Unload. flats and loading iron cars	24		
Unload. iron cars and placing rails	13	Total men	242

This day's work at track-laying, "from one end," is supposed to be the best on record. I was told by a reliable trackman, who worked with the rail-laying crew on that occasion, that the same party of 13 men unloaded from the rail cars and laid down every rail in the whole distance of 8 miles. Such must have been a remarkable test of human endurance. On another day (July 16), working from daylight to dark, 7 miles and 1040 ft, of track were laid. It is said that between Apl. 2 and Nov. 17 of that year the same outfit laid 643 miles of track, or an average of 3¼ miles for each day excepting Sundays. The man credited with the entire charge of this work, including the organization of the working forces and the arrangements for forwarding materials and supplies, was Mr. David C. Shepard, of St. Paul, Minn. An average progress of three miles of track laid per day and occasional records of four miles per day, with 160 to 185 men, has been made on other roads. On Apl. 28, 1869, the Central Pacific R. R. made a record of 10 miles and 58 ft. of track laid from one end in 11 hours. There were 96 two-horse tie teams and a very large force of men. The ties for 2 miles and a fraction had been hauled out the day before, but all the rest of the material was hauled to place on the day it was laid, some of the ties being teamed 12 miles. Some time before this the Union Pacific R. R. laid 6.8 miles of track in one day, working from 4 a. m. to midnight.

Some data on laying tie-plated track will also be of interest. In building the Kersey R. R., in 1900, the method followed was to run out the rails and ties together, on the same rail car, and lay only half of the ties in advance of the supply train. The working forces were distributed as follows: Track-laying gang, 1 foreman, 7 men with the iron car trucking rails and ties, 4 strappers, 4 spikers, 2 nippers, 1 lining ties (total 19); supply gang, 1 foreman, 12 unloading ties and rails and loading upon iron cars, 5 at supplying joint fastenings, spikes, etc., and picking up scattered material (total 18); back-tieing gang, 1 foreman, 4 spikers, 2 nippers, 1 lining ties, 4 unloading ties, spikes, etc. (total 12). In the three gangs there was a grand total of 3 foremen and 46 men. The track was laid with 85-lb. rails, Weber 6-bolt splices, and Q & W 3-hole tie plates were used on all curves. The maximum curvature was 12½ deg., the average curvature 5½ deg. and the curves constituted 43½ per cent of the length of the road. The tie plates were applied to the ties by a swedging gang in advance of the laying of the rails. The track was laid on a descending grade of 2 per cent, so that teams were not required to haul the two rail cars that were used. The cars containing material for back-tieing were cut loose some distance in the rear and let down by means of the brakes toward the material train ahead. The average length of track laid per day was 2870 ft. and the maximum 3290 ft.

In building the Point Richmond extension of the San Francisco & San Joaquin Valley Ry. material for 1 mile of track, including 4 car-loads of rails and 6 car-loads of ties, was carried out from the nearest side-track each morning. The train was made up in the following order: Pioneer car, 3 cars ties, 2 cars rails, 3 cars ties, 2 cars rails and the tool car. All the ties had tie plates embedded in them, in the yard, before shipment. The tie plates used at the joints, however, had a different spacing of the spike holes from those used on intermediate ties, and after the ties were laid one man, called the "tie-plater," took out the ordinary plates and put in the joint plates. During October, 1899, an average force of 44½ men laid an average of 2850 ft. of track per day, the maximum day's work, with 57 men, being 5400 ft. of track. The rails weighed 62½ lbs. per yard and were laid with broken joints. During February and March, 1900, an average force of 48 men averaged 3500 ft. of track laid per day, the maximum day's work being 4500 ft. of track laid with 52½ men. The rails were of 75-lb. section and were laid broken jointed. The rail-car men unloaded the rails from the material train and loaded them upon the rail car. The fastenings—splice bars, bolts and spikes—were also loaded upon the rail car, with the rails, and dropped off at proper intervals by the heelers. The ties were hauled out on a rail car and carried around to the front by hand. The general distribution of the men was about as follows:

General foreman	1
Sub-foremen	3
Strappers	4
Rail-car men	10
Spikers	8
Nippers	4
Tie line man	1
Lining ties	2
Tie-plater	1
Spike peddler	1
Spacing ties	2
Spacing rails and head bolting	2
Back bolting	2
Carrying ties	10
Picking up scattered material	1
Total men	52

It is doubtful whether an experienced man would estimate closely the cost of laying any certain piece of track of considerable length, no matter how good his facilities for getting statistics. There are so many outside circumstances to affect the work, and so many delays that cannot be foreseen, that frequently old contractors have lost heavily after having based their estimates upon conditions which their experience led them to think were like or similar to those to be met in the work at hand. The cost has ranged from $175 to $500 per mile. An average rate for long-distance track-laying would perhaps be somewhere between $200 and $250, for common labor at $2 per day without board.

On lines where there are numerous bridges to be built it is frequently the case that track-laying is seriously delayed. Especially is such liable to occur in a country where suitable timber for trestles or other bridges cannot be found and the country is badly cut up and without roads over which material may be hauled for the construction of the bridges in advance of the track-laying. It is quite commonly the practice to cut out the timber for the framed wooden bridges in advance and have it ready to be put together as soon as it arrives on the ground. Then as the track-laying forces approach the site of the bridge the timber is shipped to the end of the track, hauled ahead by teams and erected as rapidly as possible. Another scheme where streams are met and bridges are not ready, if not too high, is to "shoofly" and go around on the ground, or on cribbing, rather than to stop and wait for the bridge builders. When track is in this way laid around some point where a bridge or fill is to be built across, or is laid temporarily on the line, but at a lower level than the bridge or fill, measurements should be taken across with a steel tape to get the distance on the permanent line at grade; this is to determine where the joints should begin in laying rails on the other side, so that after the bridge or fill is completed rails can be put in without requiring short pieces. Allowance should be made for expansion, and if the measurements cannot be taken on the grade of the permanent line, plumb lines should be used. Where piles are to be driven, as in crossing swamps, small streams, gullies, etc., the track is sometimes laid on temporary cribbing on the permanent line, at or near grade. A temporary cribbing can be made quickly and cheaply with cross ties, sawed ones being preferred. The ties are easily handled and are not injured when so used. If the ravine or other depression crossed is deep the crib should consist of several tiers and sometimes it will be found necessary to lay the ties double, that is, two ties side by side in each tier, in order to make a high crib stable enough to bear the locomotive. In cases where the track-laying must be delayed on account of bridge building or for other cause, it is well to send the men back to surface and ballast what has been laid, and so keep them at work. It is a good plan to begin surfacing as soon as the track-laying gets well started, as then the crew so employed will be a reserve force from which men may be drawn to recruit the track-laying gang as the laborers become sick, sore or dissatisfied and fall out.

29. Tools for Laying Track.—Allowing for breakage and for changing men from some kinds of work to other kinds at times, the following tools will be needed for a track-laying crew of 64 men:

26 spike hammers
18 pinch bars.
12 track wrenches.
16 picks.
4 pinch bars 3½ ft. long.
2 water buckets, 4 dippers.
72 track shovels.
3 adzes.
4 chopping axes.
2 hand axes.
4 rail forks.
6 rail tongs.
2 ratchet drills and bits.
50 expansion shims, ¼ in.
100 expansion shims, ⅛ in.
200 expansion shims, 1-16 in.
1 grindstone.
3 sixteen-pound sledges.
3 adz handles (extra).
48 spike ham'r h'ndl's (extra).
12 pick handles (extra).
4 ax handles (extra).
2 track jacks.
2 tie-spacing poles.
1 drawshave.
4 claw bars.
1 push car.
3 rail cars.
1 hand car.
1 keg 10 d. wire nails.
1 keg 20 d. wire nails.
1 keg 40 d. wire nails.
1 keg 60 d. wire nails.
3 oilers.
4 gallons black oil.
4 white lanterns
2 Red lanterns, 2 red flags.
Extra white and red lantern globes.
3 monkey wrenches, 6, 8 and 12-in.
2 nail claw hammers.
1 steel tape 100 ft. long.
1 linen tape 50 ft. long.
6 track gages.
2 crosscut saws.
2 hand saws.
4 water barrels.
2 tie squares.
1 rail curver.
1 rail bender (jim-crow).
2 curving hooks.
2 track levers.
1 tie line, 1,000 ft. long.
Flat, round, quarter-round, eighth-round, and three-cornered files, three or four sizes of each.
4 horses or mules, with harness for hitching double, single or in tandem.
2 lumber wagons.
2 large tool boxes.
2 thermometers.
1 rail car clamp gage.
24 track chisels.
3 one-inch ropes for rail cars, ring and hook on each.
1 chalk line.
1 track level.
6 cold chisels.
6 switch locks.
4 doz. torpedoes.
1 tool car.
1 brace and 6 bits.
1 two-inch auger.

In case it is intended to turn the crew to surfacing and ballasting at times there would be needed, in addition to the above, 1 level board, 2 track jacks and 32 tamping picks, where broken or crushed stone ballast is used. A small car about 3 ft. long, consisting essentially of a box about 2 ft. long, 12 ins. wide and 6 ins. deep, mounted on two double-flanged wheels in tandem, so as to be pushed along on one rail, is sometimes furnished the man who distributes or "peddles" the spikes. It will carry about 100 lbs. of spikes and is quite convenient. Another receptacle sometimes furnished the spike peddler is a strong apron of thick leather or coarse bagging, which he may fill with spikes and carry in convenient position for distribution. The rail fork (*E*, Fig. 295), included in the list of tools, bears some resemblance to a track wrench. It is generally 30 to 36 ins. long and the head is slotted ¾x4 ins. In use the forked end is thrust straddle the web, at the end of the rail. It is most serviceable in handling or turning over rails in piles, or in lifting them clear of the pile so as to get hold with the hands or get a chance to pry with a bar. It comes handy in unloading rails from cars, in track-laying and on work trains when distributing rails for renewals.

30. Track-Laying Machines.—A track-laying machine is an arrangement of devices for running ties and rails to the head end of a material train. The Holman machine consists of a series of tramways or rollers about 20 ins. wide, arranged in frames or sections about 30 ft. long, which are supported upon brackets attached to the stake pockets at the sides of ordinary flat cars on which the materials for laying the track have been forwarded, no change in the cars being required. The brackets are in adjustable lengths, so that each tramway may be inclined slightly from the rear forward. The brackets which support the tie trams at the rear stand above the level of the car floor, about knee high, while those at the front end are suspended below the level of the car floor. The sections are connected up continuously, forming an inclined rollway the whole length of the train, over which the ties and rails are pushed to the front, to be lifted and placed on the roadbed by the track-layers. The rollway for forwarding the rails is arranged on one side of the train (left hand facing the front) and that for the ties on the other side. The head car of the train carries a derrick or braced tower supporting stays for the chute or end section of the tie rollway, which is extended beyond the car 35 or 40 ft. The rail tramway extends ahead of the car 8 ft. On this car, called the "pioneer car" or "pilot car," are carried the tool boxes and the spikes, bolts and splices for each train-load of material. The spikes and bolts are usually carried in a large box (called the "pig trough") 7 ft. long suspended at the head end of the car crosswise the track, about hip high. As the ties and rails are placed in position two strappers and four spikers quickly fasten each pair of rails, placing only two bolts in each splice and spiking only the center and quarter ties. The train advances one rail length at a time, the locomotive engineer at the rear taking signals from a man posted on top of the frame on the pilot car. The work of completing the splicing and spiking is attended to in rear of the train, only such work being done in front as is necessary to make safe for the train to pass. The splice bolts are not fully tightened, and it is also quite commonly the practice to place only half the ties in advance of the train.

The ordinary and most convenient rate of laying track with this machine, when full tieing ahead, is 1½ miles per day. The force required at this speed includes 40 to 45 men with the machine and 22 to 28 men behind the train, the ordinary distribution being about as follows: In front of the machine, 6 or 8 tie carriers, 1 tie liner, 1 chute man, 6 or 8 rail carriers, 2 bolters, 2 nippers, 4 spikers, 1 foreman; on the train, 2 men unloading rails, two men pushing rails, 14 to 16 men handling ties; behind the train, 2 tie spacers, 8 to 12 spikers, 4 to 6 nippers, 3 bolters, 1 spike peddler, 4 men lining track, 1 foreman. With larger crews 1¾ to 2 miles of track can be laid each day. In the construction of the Washington County R. R., in Maine, in 1899, a crew of 110 men working with a Holman machine laid 10,300 ft. of track, fully tied and spiked, in 9 hours. On the Pacific extension of the Great Northern Ry., in 1891, the average speed with a Holman machine for 82 short days during the winter was more than 1½ miles per day, and in 25 days the average speed was 2 miles per day; the best record was 140 stations, or 2.65 miles in one day.

The method of operation just described applies to what is now known as the old Holman machine, and was in vogue for many years. Important changes have taken place, however, the first of the improved machines being used in 1901. With the old machine the cars loaded with rails were placed ahead of those loaded with ties, or in rear of the pioneer car. With the new machine the former plan of making up the construction train is entirely reversed, the cars loaded with ties now being ahead, coupled in directly behind the pioneer or tool car. The cars loaded with rails are placed in rear of the ties. By this arrangement fewer tie shovers are needed, thus economizing in the number of men required to operate the machine and also to some extent expediting the delivery of the ties. The rails, instead of being pushed ahead singly, as on the old machine, are now coupled together with trace chains or with regular splices and bolts, and pulled forward in a continuous string by means of a drum and cable on the pioneer car. This drum is on the end of a shaft extending beyond the side of the car, and is located over the

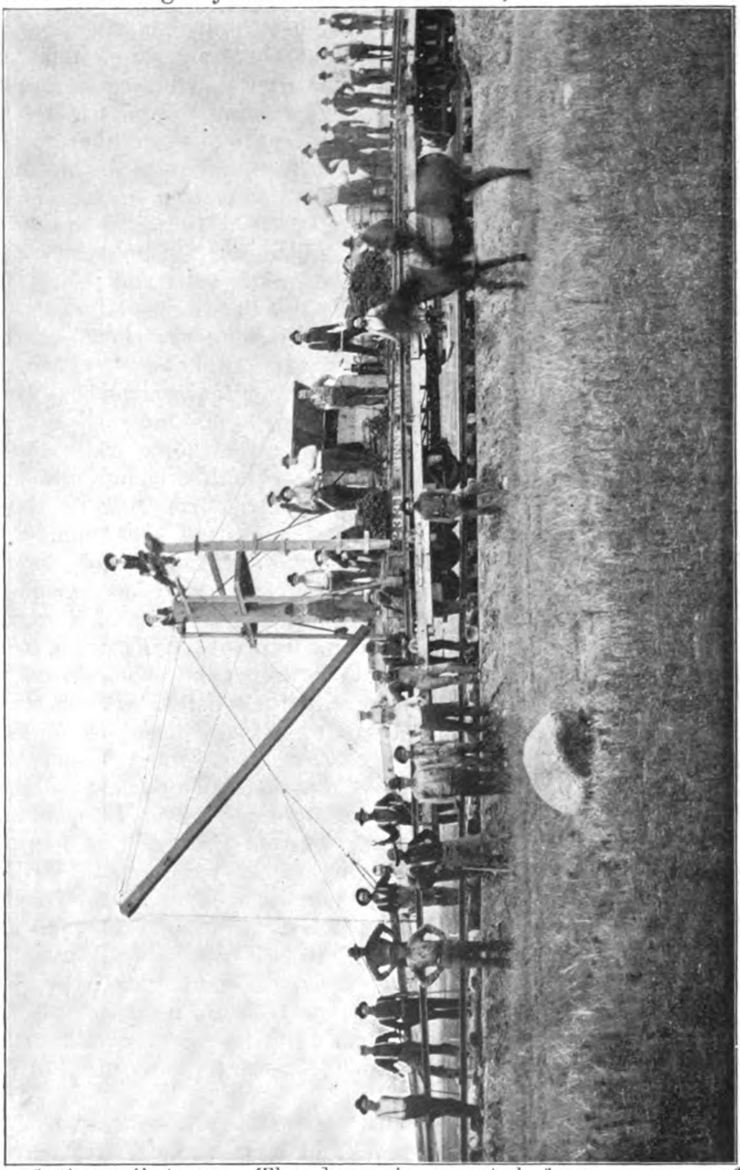


Fig. 34.—Holman-Burke Track-Laying Machine, M., St. P. & S. S. M. Ry.

center of the rail tram. The drum is operated from an axle of the car, by means of a sprocket wheel and chain. The rails are run forward over the tram in two lines, side by side, until they reach the pioneer car, where they take separate rollers, to facilitate uncoupling the splices as they are lifted down to the ties. The cable is provided with a clamp, which is carried back and attached to the rail. The mechanism is so adjusted that the rails are pulled forward at the same speed as that of the train; and as the train moves forward the length of a rail a new pair of rails is coupled on at the rear. As each successive forward movement is completed a clutch connecting the winding drum to the shaft is thrown out of gear and the clamp is carried back a rail length and attached to the rails for another pull ahead. The operation is repeated each time a length of rails is taken down by the rail gang. The new arrangement dispenses with four or five tie tramways and attachments, which are heavier than the rail tramways, thereby saving labor and time in putting up the machine. A foreman and 30 to 33 men distributed in front of the machine and on the train can lay 1½ miles of track per day.

An interesting improvement of the Holman machine, devised by Mr. James Burke, formerly general roadmaster of the Minneapolis, St. Paul & Sault Ste. Marie Ry., has been in service on that road, having been first put to use in laying the Bismarck extension from Kulm to Braddock, N. D., 80 miles, during October, 1898; since which time other machines have been built and used by railway contractors. The improvement consists in a derrick erected at the front end of the pilot car, to lift the rail from the end of the tram and lower it to position on the ties, the purpose of the device being to do the work which is usually performed by a rail-lifting gang. The arrangement is illustrated in Fig. 34, which shows a Holman track-laying machine, the rail tram of which appears to view at the front side of the pilot car and the tie tram or chute at the rear side. The derrick mast, which is stayed to the pilot car, carries a platform near its top for the pilot, who signals the engineer for the movements of the train. The rail is lifted by a chain that winds upon a windlass which is attached to the mast of the derrick and is operated by one man. In the operation of the machine one man stands at the windlass of the derrick, another attends to the grapple and one man at each end of the rail guides it to place. Before the middle point of the rail travels beyond the end of the tram the rail is caught by the grapple, at about the middle, and almost simultaneously by the man at each end of the rail. At the same time the man at the windlass manipulates the same to lift the rail and sustain it entirely from the derrick, when the two men at the ends of the rail swing it into its position on the ties. The man at the rear end of the rail heels the same to the forward end of the rail previously laid, while the man at the forward end of the rail moves it to proper alignment. In this way the rails are laid without any lifting by hand, and the arrangement does away with the laborious and slower way of carrying them by hand from a tram which projects only a few feet beyond the front end of the car.

On one occasion this machine, in 10 hours, handled the material for laying 12,000 ft. or 2.28 miles of track. This track was laid by 93 men stationed as follows: 12 men carrying ties from the end of the tram, 1 man running the tie line, 1 running the tie spacing poles, 1 holding ties at the end of the tram, 1 tapping rails back with the spike maul to insure proper expansion, 3 handling rails with the derrick, 1 on windlass of the derrick, 3 spikers and 3 nippers ahead of the pilot car, 1 gage bearer, 2 bolters ahead of the pilot car, 1 bolter on the platform putting on angle bars as the rails were shoved by him in the tram, 1 man on the pilot car keeping bolts, spikes and angle bars in place, 6 men putting ties into the tram, 12 pulling ties to the front, 2 moving rails into the tram, 3 pulling rails. In rear of the train there were 10 spikers, 5 nippers, 2 spacing ties under joints, 2 spike and bolt peddlers, 6 bolters, 6 men lining track and one man carrying water.

There was 1 foreman in charge ahead of the pilot car, 1 in charge of the men on the train, 1 in charge of the men in rear of the train, 1 lining track and 1 general foreman. One conductor and two brakemen handled the train. The track was laid with 60-lb rails, 16 ties to the rail and four-bolt angle bars. This was the largest day's work. In laying 77 miles of track the average fair day's work was two miles, with a few less men. According to official statements this derrick put the question of rails out of the way, so far as the speed of track-laying was concerned, as then the amount of track that could be laid was determined only by the number of ties that could be got to the front through the tie trams, carried away from the end and placed for the rails to be laid upon. Previously to that time the part of the work most responsible for delays was the slow and laborious way of handling the rails by hand. When it was desired to lay two miles of track per day, it required 14 men to handle 70-lb rails and 12 men for 60-lb. rails. The spikers were obliged to wait until the second rail was laid before they could drive any of the spikes, there being so many men in the way, and the large body of rail men were then obliged to wait for the spiking to be done. With the

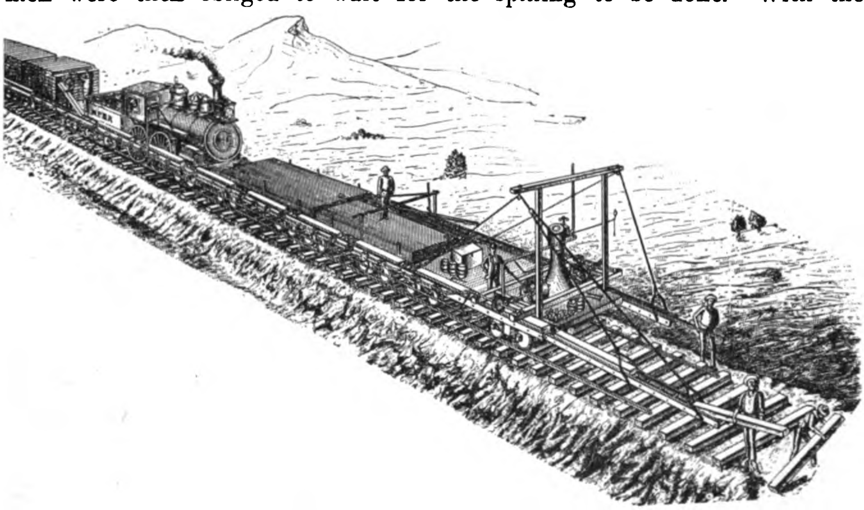


Fig. 35.—Roberts Track-Laying Machine.

derrick and the rail tram extended out to 16 feet ahead of the car the rail first to be laid when the stop is made is out and suspended, held by the derrick ready to be dropped the instant the car stops. By this time the second rail has traveled forward as far as the point where it is to be laid, and is quickly dropped to its position on the ties. It is figured that the derrick saves from $12 to $14 per day, over the old method of lifting the rails by hand; and not only this, but it increases the efficiency of the whole machine.

The Roberts Machine.—The general arrangement of the Roberts track-laying machine is similar to that of the Holman, except that in the former the tram rollers are driven by steam. The conveyor part of the Roberts machine (Fig. 35) consists of rollers arranged in framed sections about 32 ft. long, supported at a plane just below the bed of the cars on brackets hung from the stake pockets. These tramways may be attached to any kind of car—a gondola, box or stock car, as well as a flat car. The supporting brackets are inserted from the bottom of the stake pockets, so that ties which project over the edge of flat cars do not interfere with the work of attaching the machine to the cars. Alternate rollers are bevel geared to a shaft extending the length of the cars, driven by an upright steam engine on the pilot car, taking steam from the locomotive. The shaft is in sections and provided with universal couplings, so as to allow for angularity occasioned by curves in the track. As half of the rollers (alternate ones) are idle, the live ones on the tie side are corrugated or fluted, so as to bite into the tie and force it along. The upper surface of the live rollers is about 1 in. higher than the idle ones, which throws most of the weight on the live rollers. The tie trams can be operated when filled with ties their entire length, the maximum rate of delivery being 50 ties per minute. The connection between the driving shafts and the engine is by friction clutch, so as to prevent breaking in case of clogging or sudden stopping of the shaft in any manner. The rails are carried along one side of the train and the ties along the other, as in the Holman machines, but the two sets of shafting may be driven independently, if desired. The flats loaded with rails are usually placed ahead of the locomotive, immediately in rear of the machine car, and the ties behind the locomotive; it is necessary therefore to arrange the rollway so as to carry the ties past the locomotive. In this machine the tie chute is extended 60 ft. ahead of the pilot or machine car, such arrangement enabling the tie men to keep out of the way of the men laying the rails, which are delivered but a little in advance of the end of the car. In order to allow room for bolting, the end rail chute extends 6 ft. ahead of the end of the car. The front end of the machine car is used to carry splice bars, bolts and spikes, where they will be within easy reach of the track-layers. The rear part of the car carries tool boxes and such short pieces of rail as may be necessary.

In the operation of the machine eight men are required on the train, in the following positions: Four men throwing ties into the tramways, 2 men loading rails into the rail trams, 1 man to operate the engine on the pilot car, and one oiler and pilot-car assistant. To facilitate close movement and prevent running off the end of the track a brake is set on each end of the train, to take out the slack between the cars. The locomotive engineer is signaled by means of a small whistle attached to the steam piping on the pilot car. A feature of great convenience in the operation of the machine is the flexibility of which it is capable in the delivery of material, it being equally convenient to forward pieces from any car of the train at any time, and in any desired order. Thus if hardwood ties are to be used on the curves and softwood ties on the tangents the cars may be coupled into the train in any convenient order and the ties of particular quality sent forward on the trams as required, without reference to the location of the car or cars on which they are carried. The same convenience of delivery applies also to the forwarding of curved or short rails from whatever car of the train they are on, and just at the particular time or place they may be in demand. For the building of temporary structures where small bridge or culvert openings occur the timber or other material may be carried on extra cars at the rear of the train and sent forward over the tramways as needed. It is also to be noted that the labor required in connection with the operation of the machine and the speed of delivery are independent of the length of the train, since the material requires no attention from the time it is put into the trams until it arrives at the front. From the fact that no labor is required to push the material forward the practice in vogue when using this machine is to full tie the track ahead. As the speed of delivery is regulated by steam power and the work of throwing ties into the trams nothing is to be gained in speed by half tieing ahead of the train.

The usual method of procedure with the Roberts machine is to full tie, half bolt and quarter spike the track ahead of the train, completing the work with a gang of bolters and spikers in the rear. The convenient average speed of track-laying seems to be about 2 miles per day, with a capacity for better records by rushing the work. The force required at a 2-mile gait is three foremen and 65 to 80 men, all told, distributed about as follows: Ahead of train, 8 placing rails, 8 to 10 carrying ties, 4 head spikers, 2 head nippers, 3 head strappers, 1 tie liner (total 26 to 28 men); on machine and train, 8 men, as already noted; in rear gang, 4 to 6 back bolters, 2 spike and bolt peddlers, 12 to 20 back spikers, 6 to 10 back nippers, 2 spacing ties, 5 lining track (total 31 to 45 men). In laying the Columbia & Western branch of the Canadian Pacific Ry., in 1899, the average speed with this machine was 1000 ft. of track laid, complete, per hour. In this work no spiking was done in advance of the machine or train. The rails were held to gage by "bridle bars," two in each rail length on tangents and three on curves. These bars consisted of ⅝-in. rods flattened at the ends and turned up to hook over the rail flange, on the outside, with a slot at the inside edge of the rail flange, into which a spike was dropped to secure the rail. The crew ahead of the machine contained 22 to 24 men, including 1 tie line stretcher, 8 to 10 tie carriers, 1 tie marker, 2 tie liners, 8 men placing rails, and 2 strappers. At the most rapid rate a pair of rails was laid every minute, and sometimes a little quicker. In rear of the train

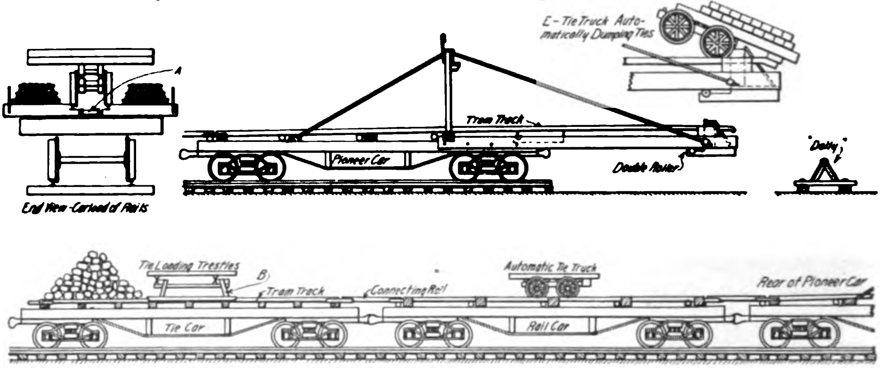


Fig. 36.—Details of Harris Track-Laying Machine.

the bridle or gage bars were taken off and sent forward over the tie trams in a long, narrow box. The tie plates, which were used, were dropped off the train and placed under the rails at the rear. The grades being heavy, two medium-weight consolidation locomotives were required to push 14 car-loads of material. The track-laying machine would work on 14-deg. curves, but not on a 22-deg. curve on which it was tried. A night train crew brought up during each night the loaded cars for the next day and at noon did the switching and made up the material train for the afternoon. In extending the St. Louis & San Francisco R. R. from Sapulpa, Ind. Ter., to Sherman, Tex., in 1900, 2.27 miles of track was laid each day of 10 hours with a Roberts track-laying machine, "without difficulty;" and during the same year, in laying extensions to the Chicago & Northwestern Ry., in Iowa, a machine of the same type made a record of 2½ miles per average day of 9 hours.

In the extension of the Chicago, Rock Island & Mexico Ry. southwest from Liberal, Kan., a Roberts track-laying machine was used, and when this work was started, in 1901, it was decided to call 2½ miles of track a day's work, regardless of the time taken in laying the same. This work was invariably performed in seven hours. The material was taken out in two trains: one in the early morning, the men returning to camp as soon as this was laid, when the second train would be taken out. The best time made in laying 1¼ miles of track (half a day's work) was three hours flat. This was done several times when the grade was favorable. The track-laying force consisted, on an average, of 190 men. The steel was of 80-lb. section, with Continuous joint splices. The ties were oak and hard pine. The surfacing gang, of about 250 men, followed the front as closely as practicable, generally one side-track in rear of the front camp. The telegraph line was built as rapidly as the track was laid, the telegraphic supplies forming a part of the track-laying material train. The fence gang was kept immediately in rear of the surfacers. The work of completing the line was practically finished simultaneously, in so far as track, telegraph line and fencing were concerned. The only delays sustained were those incident to overtaking the graders occasionally.

The Harris Machine.—The Harris track-laying machine consists of ordinary flat cars fitted up with a rollway for forwarding the rails and a tramway for a push car or truck on which the ties are run out to the front. Five 6x8-in.x11-ft. timbers or switch ties are laid across each car and spiked fast, and on these is laid a tram track of ordinary rails. On the old machines (which went out of use in 1900) the gage of this tram track was 8½ ft., but on the machines of later design the gage is only 2 ft., and the track is laid along the middle of the cars. Between the rails of this track, and on a level with base of rail, there are cast iron rollers 15 ins. long, on which the rails for track-laying are pushed to the front (*A*, Fig. 36). On the cars which carry the rails the cross timbers are framed out at the middle and the rails of the tram track are depressed to bring the top of rail flush with the tops of the timbers. This arrangement permits the supply rails, which are carried in piles on either side of the tramway, to be easily slid or rolled onto the rollers. Only the cars loaded with rails have the rollway, and these cars are, of course, placed ahead of the cars loaded with the ties. On the cars loaded with the ties the tram rails are laid on top of the cross timbers, and alternately between these long ties or timbers there are 8 ft. ties to afford close supports for the truck-loading horses or "trestles," to be described presently. The gaps in the tram track between the cars are closed by short pieces of rail having the bottom flange cut off at each end so that the web may be dropped between splice bars bolted to the ends of the fixed tram rails on the cars. Allowance is made in the length of the short connecting rails for slack between the cars. On the front car the tram track is extended 20 ft. ahead of the car and is held up by truss rods carried over a framed bent 10 or 12 ft. high and anchored at the back of the car. The ties are piled across the tramway, and the spikes, bolts and splice bars are chinked into spare space on the rail cars. The cross timbers, which project over the sides of the cars, carry a running plank on either side for the men to stand upon while loading the ties. It also affords a footway for the men pushing the tie truck and a place for the rail men to step aside while the loaded tie truck is passing.

The ties are not loaded upon the tie truck direct, but are first placed crosswise a pair of portable wooden horses or "tie-loading trestles" (*B*, Fig. 36) stood parallel with the tram track, on either side. These tie horses each have a top piece or upper frame carried on links, which is raised 4 ins. before the ties are placed upon it. After a truck-load of ties has been placed across the horses the empty truck, which is 2 ins. lower than the tops of the horses in their raised position, is run between the horses and under the pile of ties, at the same time automatically disengaging a latch which holds the load of ties in the raised position. In this manner the load is caused to drop 2 ins., onto the truck, the top pieces of the horses dropping 2 ins. further, clear of the load and out of the way of the movement of the same. The truck, as thus automatically loaded, is pushed to the front and the work of loading the horses is repeated. The horses stand on runners, and as each truck-load of ties is delivered they are pulled ahead to a new position within reach of the receding tie pile on the flat car.

In starting out to lay track the rails are thrown onto the rollway with a rail fork and pulled ahead to the pilot car by men with tongs or hooks. Here they are spliced and bolted together four rails at a time—that is, two rails in a stretch for each side of the track—using two bolts to each splice, allowing for expansion and putting in the expansion shims. In the meantime the tie truck or tram car has been loaded and pushed forward, and at the end of the tramway is run against chocks or stop blocks. (*E*, Fig. 36). The tram car body is made in two parts, the upper of which slides between guides, over the lower part, on rollers, so that when the car is brought to a stop at the end the load is shifted forward 30 ins., causing the car to overbalance, tilt forward and dump itself, throwing the ties crosswise on the roadbed. The car is then righted and run back for another load, while the rails which had been spliced and lying on the pilot car are run ahead off the car onto a portable dolly about 30 ins. high standing on runners, on the ties, about 25 ft. ahead of the extended tram track. Suspended from the cross timber at the end of the tram track there is a roller about a foot lower than the rollers on the flat car, which serves as an intermediate support for the rail between the end of the car and the dolly. The rails are run to a position opposite their place in the track and are then lifted down and heeled into splice bars fastened loosely to the last rails laid. In laying broken-jointed track the rails on the "long side" are simply run a half rail length further ahead on the rollers. As soon as the rails are in place the track is quarter spiked and the train is moved ahead 60 ft.

The foregoing is known as the method of "standard 60-ft. set-outs" and is the usual way of proceeding to lay 2 miles of track per day. In this case 34 to 42 men are required with the machine, according to the weight of rail, quality of the ties (soft or hard wood), efficiency of the men, organization, &c. Of this crew 14 men, called the "top force," are engaged on the cars as follows: four men loading ties, 3 men running tie car, 1 man breaking out rails onto the rollers, 4 men pulling rails with hooks and delivering them ahead, and 2 top bolters. The "ground force," or the men ahead of the machine, are distributed as follows: One man with tie line, 1 man with spacing pole and marking ties for line rail, 1 spike peddler, 1 man serving splice bars, 8 spikers, 4 nippers, 2 men carrying dolly, 1 "expansion man" (with sledge to drive rails back when necessary), 1 heeler (who, as a rule is the foreman of the ground force), 2 bolters and 4 to 6 extra men; or a total of 26 to 28 men. With soft wood ties the 4 to 6 "extra men" are usually dispensed with, and sometimes the force is cut down one or two more. The usual practice in laying 60-ft. "set-outs" is to half tie ahead. If it is desired to work a smaller crew, laying 1 to 1¼ miles per day, the rails are run down singly, or in 30-ft. "set-outs," the train moving ahead 30 ft. at a time; or by using the same force, half tieing the track and handling single rails in 60-ft. "set-outs," 1¼ to 1½ miles of track can be laid per day. For fast work, as when it is desired to lay 3 miles per day, a larger force is put on and the rails are handled in spliced sections of three each, or in 90-ft. "set-outs," the train then moving ahead 90 ft. at a time. In this case three dollies are used ahead of the pilot or pioneer car in running the rails to place.

With the Harris machine the track-layers in advance of the train are not divided into separate squads designated as tie carriers, rail carriers, spikers, etc., as in usual practice with other machines. Each truck-load of ties contains the proper number to lay the "set-out" of rails (30, 60 or 90 ft. of track, as the case may be) and as they are dumped the momentum of the truck throws them sprawling ahead over about 30 ft. of roadbed. As the rails cannot be laid until the ties are placed the whole track-laying gang ahead of the car, except the tie-line man, the two bolters, the splice carrier and the "fiddler" or tie marker, is first engaged in placing the ties, which is quickly done. The same men then run out the rails and lift them down and then divide up into spiking gangs and make ready for the train to advance. In rapid work the track in advance of the Harris machine is only half tied, the remainder of the ties being dropped off the box or other cars in which they happen to be loaded and which are coupled in behind the tramway cars. This arrangement saves transferring half the ties to the machine cars.

Before referring to records of work performed in connection with the use of this machine the difference in the methods of handling the ties on the old and new machines should be explained. On the old machine the tie truck had to be built wide, for the wide-gage track, and it was high enough to straddle the piles of rails on the rail cars. The tie truck for the machine of later design is narrow, running between the rail piles, as shown at the left in Fig. 36, and it is much lighter and easier to handle than the old device. On the old machine the ties were loaded directly upon the truck, by hand. For rapid work two tie trucks were used after the train became half unloaded, as then some time was lost in pushing the truck over the increased distance. In that case the hindermost truck was being loaded while the forward one was being pushed to the front and dumped. The rear truck was made somewhat higher than the other and when they met the load was transferred by sliding the ties onto the lower truck. The automatic tie-loading device of the present machine enables faster work to be done than was possible with the old machine. On the present machine the tie truck can be shoved forth and back on the run, if need be, stopping only an instant at either end for the truck to receive or dump its load. It is thus possible to keep a loaded tie truck on the move half the time. At the same time the present machine is more adaptable to the convenience of working a small crew and laying track at moderate speed, when desired. Four to 6 men can load and deliver ties for laying a mile of track per day; in laying 2 miles per day 7 or 8 men are required. Four men can work at loading the horses—two men placing the ties upon the front end of the horses and two more shoving them back and piling them up.

A seeming drawback with the Harris machine is the necessity for transferring the rails and at least half of the ties to the specially equipped flat cars. In fairness, however, it should be considered that both rails and ties are frequently shipped in box, stock or gondola cars, in which case the rails must be transferred, in any event. In the yards, where the cars between which the transfer of materials is to be made can be switched to stand side by side or end to end, the cost of loading the "machine cars" is but very little more than the cost of taking the material out of the cars in which it was shipped. There is also an advantage in having the material on the machine cars, for as soon as they reach the front there is no delay in starting the work, whereas with other machines some time is lost in putting on and taking off apparatus. When working with the Harris machine it is customary to rig up as many cars as may be necessary to have in order to keep the transfer gang in the material yard steadily at work while track is being laid at the front. This arrangement should always provide loaded "machine cars" as they are needed. The equipment of the cars is comparatively inexpensive, as the material required is standard track material and its usefulness for further service in the track is not impaired, except in the case of the framing out of the cross timbers on the rail cars. The labor of laying the tram track on the flat cars and of dismantling the cars after track-laying has been completed is small. The narrow-gage tramway, located as it is along the center of the train, is less distorted in rounding a curve than is the case with a track or devices at the sides of the cars. As a practical test of this matter, one of these machines was successfully used in laying track on the 24-deg. curves of the Montana R. R., a standard-gage road running out of Lombard, Mont.

As a matter of record 3.2 miles of track have been laid with this machine (old pattern) in 9 hours. On the Chicago, Kansas & Nebraska Ry. (now Chicago, Rock Island & Pacific Ry.) in 1887 the average record for 132 days with the Harris machine was 2.18 miles of track laid per day, with a total force of 3 foremen and 100 to 115 laborers, including the gang which transferred ties and rails to the material cars. In building the Guernsey extension of the Burlington & Missouri River R. R., in Wyoming, in 1900, a record made with one of the improved machines (Fig. 37) was 3750 ft. of track laid in 2 hours and 35 minutes. The track was laid with 75-lb. rails and oak ties, and was full tied ahead of the machine. The crew on the cars and ahead of the machine consisted of 28 men, distributed as follows: ground force, 1 tie-line man, 1 spacing-pole man and tie marker, 1 spike peddler, 1 splice carrier, 1 heeler, 6 spikers and nippers, 2 bolters and 4 or 5 extra men; top force, 4 men loading ties, 3 men on tie car, 1 man breaking out rails, 2 men pulling rails. The average day's work with this crew, laying by 30-ft. "set-outs" and full tieing ahead, was 6000 ft. of track per day.

The Hurley Machine.—The Hurley track-laying machine, which was used for the first time in the construction of a new piece of track for the Bessemer & Lake Erie R. R. in 1902, consists principally of a machine car 55 ft. long carrying at the front end a pair of cantilever steel trusses extending 60 ft. ahead of the car, and at the rear end a raised platform supporting a boiler and two reversible stationary engines of 100 h. p. Following this there is a tender car carrying a water tank and fuel on a raised platform. Coupled in behind the tender are the cars loaded with ties, the cars loaded with rails bringing up the rear. At the middle of each material car, on each side and about a foot inside the edge, there is a roller, used for moving the rails ahead. The rails are coupled up with two bolts in each splice and are pulled forward over the rollers in two lines, one on either side of the train. On the tie cars the lower tiers of ties are laid lengthwise the car and clear of the rollers, so that there are open spaces for the rails to pass underneath the ties that are piled crosswise. On the machine car each line of rails passes between two sets of steam-driven friction rolls which drive them forward and also pull the whole string of rails behind. As each string of rails is fed forward to the machine car, rails are coupled on behind at the rail cars at the rear of the train. This can be done one rail at a time, but in practice about six rails (or one from each of the rail cars) are coupled on at a time. One rail on each of the cars is shoved out and run ahead on dollies and coupled to a rail on the next car ahead, this being done while the rear end of the long string of rails is moving by. As soon as the rear end of the line of rails arrives at the front end of the newly spliced section the latter is quickly coupled on by means of two pairs of clamps connected by a short chain. This chain has an adjustable attachment whereby the rear section is pulled up to a close joint and held there while the splice bars and bolts are being applied, the line of rails, meanwhile, being pulled toward the front.

The ties are carried forward on the two lines of rails. At the front end of the first tie pile back from the machine car, the ties are rolled down and laid across the rails roughly spaced at the same intervals as they are laid in the track. As the rails move forward they therefore convey all the ties necessary to lay them. Figure 5A shows the machine car, and three material cars, with the rails and ties as they appear when moving forward over the train. As the ties arrive at the machine car they are caught on an endless chain and conveyed up an incline over the top

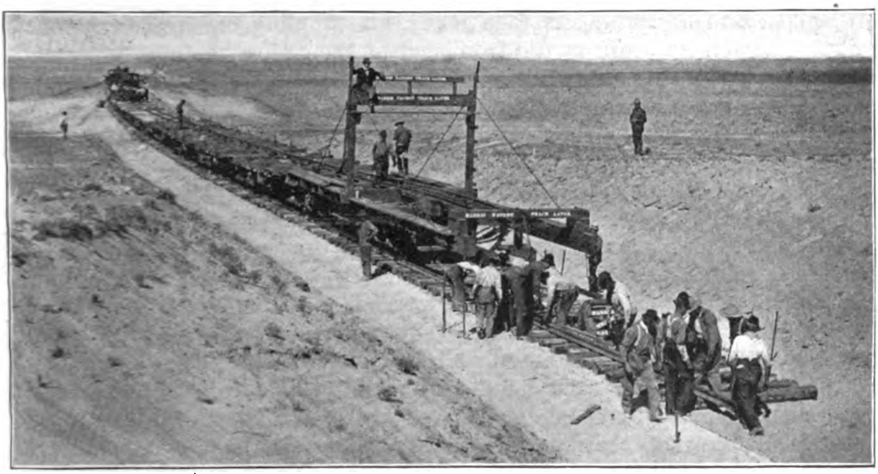


Fig. 37.—Improved Harris Track-Laying Machine.

chords of the cantilever extension, and as they arrive at the front end of this they slide down an incline and fall upon the roadbed crosswise the alignment of the track. In this manner they drop approximately to place, and it is only necessary for two men to square them around and properly space them. In this way the roadbed is constantly supplied with ties in advance of the laying of the rails. Figure 16 illustrates the delivery of the ties in this manner.

The trusses of the cantilever extension of the machine car are 8 ft. apart, laterally braced together, and stand 8 ft. clear of the roadbed, or high enough to allow free action of the spikers underneath. Attached to the bottom chord of each truss there is a channel, in which are power rollers for moving the rails forward. As the rails arrive at the front of the machine car they are uncoupled, one at a time, by taking out the rear bolt at each joint, leaving a pair of splices loosely coupled to the rear end of each rail. A rail on each side is then sent forward under the overhang to a point about 20 ft. ahead of the machine car, where it is grasped by a pair of hoisting tongs and lowered by one man onto the ties below. To explain this movement a little in detail, the rail is gripped by the tongs somewhere near the middle. These tongs are suspended from a bar, at each end of which there is a stay which maintains the bar parallel with the rail. This bar is supported from above at two points, so that the rail is held in a horizontal position whether gripped exactly at the balancing point or not. In dropping the rail to couple on at the end of the last one laid, it is lowered to within about 2 ins. of the rail already laid, and when the car has moved it nearly to place the heeler swings it ahead 1½ or 2 ft., so that the rail is dropped to place an instant before the car has been moved far enough to place it there if it was dropped vertically. There is therefore no chance for the machine to drag the rail ahead should the man be a little tardy in releasing the tongs. The operations are so gaged that the rail is set down just about a foot in advance of the last rail laid and spiked. The rail is then pulled back by the track-layers, and as the splices with one bolt are already in place, the joint can be very quickly coupled. To facilitate the work of getting the splice bars home, use is made of a U-shaped clamp worked by a lever and eccentric. This tool quickly forces the bars to a fit and brings the ends of the rails into line before the bolt is tightened. While one man on each side is doing this the quarters and centers of the rails are spiked and everything is then ready for coupling on another pair of rails. The spikers begin at the front end of the rail, each time, and work back toward the advancing car, so as to be out of the way when the next pair of rails is lowered. The length of the overhang is such that the rails for the two sides of the track can be set down in pairs when laying with either square or broken joints.

The train moves gradually forward at the rate of 20 to 30 ft. a minute, and with experienced track-layers it is not necessary to stop. With inexperienced men a brief pause is made each time a pair of rails is disconnected on the machine car. The machinery is so geared that the material is moved forward over the cars at exactly the same speed that the train moves over the track. Chief attention is therefore paid to lowering the rails, splicing them on ahead and partially spiking them, for as fast as the train moves ahead the material is in place for laying the track. The rollers on the overhang are driven about five times as fast as the main feed rollers, so that there is no trouble in keeping the front end of the machine car cleared for action. While one pair of rails is being lowered to the ties another pair can, if desired, be run forward ready for the tongs as soon as the car has advanced sufficiently far ahead. When laying on curves the incline at the front of the cantilever extension is swung into position to land the ties on line. The motive power for the train is supplied by the machine car, so that no locomotive is required. Power is applied to all three of the trucks supporting the car, and the machine has shown itself able to handle 19 car-loads of ties and rails on a six-tenths per cent grade over a very rough roadbed. When the machine is transported from one road to another the cantilever extension is unjointed and let down upon a separate car. The tender car is generally used for this purpose. Besides the water tank on the tender car, three of the tie cars are equipped with tanks underneath, from which water is pumped into the tender tank from time to time while track-laying is in progress. The purpose of these storage tanks on the tie cars is to keep the tender tank supplied with water so that it may remain with the machine car at all times. The weight of the machine car is 50 tons. Owing to the excess of weight at the head end, this part of the car is carried on two trucks, which is supposed to be a better arrangement for running over partially spiked rails than that of carrying all the weight of the front end on one truck.

It is said that 30 to 35 experienced men working with this machine can lay 2 miles of track per day. The features of advantage are several. The rails and ties are moved by power, and the ties are dropped to place on the roadbed without lifting or carrying by hand. Six men do all the labor necessary to transfer the ties from the cars to the roadbed. The ties are dropped well in advance of the rails without interfering with any part of the work. The rails are lowered to the ties without hand labor. The men are so distributed about the work that no one is in another's way. The most important consideration from an economical standpoint is the fact that the use of a locomotive with the track-laying outfit is dispensed with.

General Considerations.—It has already been seen that the methods of laying track with these different machines are practically the same, so far as the work on the roadbed is concerned, the only differences in any way being in the manner of getting the materials to the front. In comparing what is commonly, but erroneously, called "machine" track-laying with "hand" laying, the machine and the men employed on it stand against as many tie teams, rail cars and men loading and driving the same as may be required to forward the same amount of material in the same time. In case the ties are hauled out on rail cars and carried ahead by hand the comparison would include as many of the tie carriers so employed as are in excess of those carrying ties from the chute of the track-laying machine to lay the same number in the same time. This is because the tie carriers with a track-laying machine carry the ties only such a short distance that they may be considered to offset or stand against the tie placers who work in connection with tie teams. The men who carry ties ahead from a rail car must walk some little distance, usually 80 to 100 ft. or farther. In other words, to get at the economy of a track-laying machine we have to take account of the labor required by either method in forwarding the rails from their position on a flat car of the material train to the end of the track, and that of forwarding the ties from the *cars in which they are shipped,* to their approximate position in the track. The work of half tieing operates the same in either case. The same number of tie placers, liners and spacers, rail carriers (except with the Hurley machine), strappers, spikers, nippers, spike peddlers, etc., are required for the same speed of track-laying by either method, whether the track is full tied or half tied ahead of the material train.

The work required to put the track materials together is always about the same, once they are on the ground, whether it is all completed ahead of the material train, or partly done and then completed by a rear gang. The advantage in deferring part of the work until after the passage of the material train is that there is less interruption in the delivery of the material from the train. This advantage is greater where track-laying machines are being used than it is where the case is otherwise, for the number of men who can work in front of the machine without interference is necessarily small relatively to the number required to complete the track as fast as the materials can be forwarded over the train. For fast work at machine track-laying it is desirable, therefore, to do just as little work in advance of the machine as will make safe for the train to pass over the track. One measure already referred to in connection with the work on the Columbia & Western road, that of using bridle or gage bars in order to omit the spiking in advance of the machine, is now quite commonly in practice. Another expedient in vogue is to have the strappers begin the work of splicing by putting the splice bars loosely on the ends of the last rails laid, with one bolt in place. When the next rail is heeled the strapper pries open the splice bars with his wrench, to receive the rail end, inserts the expansion shim, puts in one more bolt and goes ahead to the end of the last rail laid. To avoid delay occasioned by hard-turning nuts two slotted bolts with cotters have been used to hold each splice temporarily. As it is not usual to tighten the splices ahead of the machine the spiking of the joints cannot then be properly done and such work is also omitted, the rails being held to gage by spiking the centers and quarters.

The claim for track-laying machines is economy in the cost of handling the material rather than a maximum speed of laying track. According to estimates and comparisons based on actual work under similar conditions a saving of $50 to $100 per mile in total cost of laying track has been shown in favor of track-laying machines. While, for the purposes of track-laying, their capacity for forwarding material ahead is practically unlimited, the movements of the head track-layers are necessarily hampered, since only 30 to 60 ft. of track is laid at a move of the train, and of course the number of men who can be worked in this distance is necessarily a comparatively small party. It is possible to put enough teams, rail cars and men to work to lay more track per day than can be done with any number of men working with a track-laying machine, as already indicated by the records, but the cost of rushing the work in this manner is excessive. Under certain conditions, however, such as are found in mountain regions where the grades are heavy and room at the side of the track is scarce, or in swampy country where teams would get mired outside the roadbed, the track-laying machine may, besides contributing greatly to convenience, enable a more rapid speed in construction than could be accomplished without it. It does not work as well on sharp curves as on tangents, and formerly it was not thought advisable to employ it except on construction of considerable extent. Still, the use of track-laying machines has been growing during recent years, notwithstanding that railway building for the most part is now confined to short stretches of branch lines, side-tracks and second tracks. Generally speaking, conditions in track-laying now are different from what they were in the days when so many long lines were being built, and the class of work is different. The cost of the work is now more carefully considered and there is less of the old-time reckless haste. It is the tendency of the age to substitute machinery for flesh and blood.

It is frequently desirable to start the track-laying at a slow pace, working a small crew and laying a mile or perhaps less of track per day, and then, when all of the grading has been completed, push the work along at double this speed. Where such is the purpose a track-laying machine is well suited to the work, because the change in speed can be made without change in the organization of the forces and by hiring fewer extra men than would be the case if the material was handled with teams and rail cars.

31. Highway Crossings.—In laying track the grade crossings at the public highways must be attended to promptly. Planks may be laid temporarily as soon as the ties are spiked, and a heap of dirt at the ends of the ties may serve for an approach. After the track has been surfaced and ballasted, however, or when putting in a crossing in old track, it is important to first see that the track at that point, and for some distance each way, is in good line and surface before laying the plank. They should then be put down with 8-in. wrought timber or boat spikes so firmly that a dragging brake rod or piece of car truck will split out a chunk before it will tear the plank out or loosen it. The standard crossing spike of the Pennsylvania R. R. is 8 ins. long under the head and $\frac{1}{2}$ in. square in section. The head is $\frac{3}{4}$ in. square and $\frac{1}{4}$ in. deep, and the wedge-shaped point is $1\frac{1}{8}$ ins. long.

There is a saving of lumber in using only four planks at a crossing—one each side each rail—but if the highway travel amounts to anything there is no economy in sparing the plank. The practice of using only two planks inside the rails and filling the space between them with gravel, broken stone, cinders or earth is sure to result in an ugly hollow, in time, wherever the travel is considerable. Such is unpleasant to road travelers, the inside planks wear out rapidly and the material used to fill the space is constantly being carried or pushed by wagon wheels into the flangeways, to be packed down by the car wheel flanges and require picking out by the section men every few days. It is better to use planking all the way across; it makes a better crossing every way, lasts longer, and is much cheaper to maintain than one at which a space is left unplanked, to be refilled every little while. The space between tracks is another place where troublesome depressions are liable to result from highway travel, and at crossings with busy roads or streets it might pay to pave such places or plank them entirely over.

White oak and hard pine are the kinds of lumber most commonly used in road crossings. Crossing plank should be at least 4 ins. thick, and 12 ins. is a convenient width. The length of the crossing should conform to the required width of the traveled highway, which is seldom less than 16 ft. For a single driveway or private crossing planks 12 ft. long are long enough, but where the whole width of the road or street is planked in they may be of any convenient length and be laid to break joints. On the outside the planks should be laid against the rail head, notching out the under corner to fit over the spike heads in case the plank would stand too high by resting on top of them. The position of each spike head may be found by placing the plank against the rail, in its proper position, and striking it a blow on the top approximately over each spike. The position of the spike heads will then be indicated by the indentations. It is better to notch out for the spike heads than to chamfer off the whole under edge, as such weakens the plank. The top of the crossing plank should come flush with the top of the rail, or not to exceed $\frac{1}{4}$ in. below it, and if the thickness of the plank does not correspond to the hight of the rail (it is usually less) strips of board or filler pieces may be nailed to the tops of the ties to shim the planks to the proper hight. A space $2\frac{1}{2}$ ins. wide should be left for a flangeway inside each rail but not more, because if made too wide it forms a trap to catch the hoofs of horses or cattle. It is well to lightly bevel off the corner of the plank next the flangeway, to prevent the wheel flanges from peeling off slivers.

The top edge of the plank next the flangeway in the standard highway crossing of the Pennsylvania R. R. (Fig. 38) is chamfered 3 ins., which is considerably more than is required to clear the wheel flanges. In this style of crossing the two inside planks are connected at the ends by short pieces of plank of the same thickness, enclosing a rectangular space which is filled with broken stone. Outside the rail the planks are laid in the usual way. On crossings planked solid between the flangeways in the usual manner four 12-in. planks will not quite fill the whole space, but cracks an inch or so wide left between the planks do no harm and soon get filled. The ends of all the planks, both outside and inside the rails, should be adzed to a slope after they are in place; but the planks should first be cut to such length that each end rests on a tie, to which it should be spiked; and the planks inside the rails should be cut to even lengths. Such work gives best security against dragging parts of cars. On some of the crossings of the Pennsylvania R. R. there is a sloping steel plate at each end of the crossing plank. The ballast between the ties, under crossing planks, should be dressed off about an inch lower than the tops of the ties. If it is permitted to touch the planks it is liable to lift them in case it should heave in winter. In laying crossing plank they should be placed to bring the convex side of the grain upward, as in Fig. 39, in order to shed water. If the concave side is upward the dish of the grain will hold water to rot the plank.

Private farm crossings or other crossings but little used may be, and usually are, more cheaply built than the crossings for well-traveled roads. A plank each side each rail with a filling of ballast between the two inner planks serves the purpose well enough, and hemlock or other cheap lum-

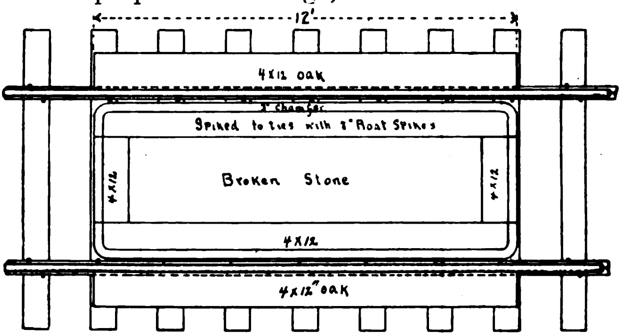


Fig. 38.—Highway Crossing, Pennsylvania R. R.

ber is sufficiently durable. In parts of the country where extra wide harvesting machinery is not used a private crossing 8 ft. long, made by cutting 16-ft. planks in two, is sufficiently serviceable. In fact it is not necessary to use plank at all. If the use of the crossing is to be only occasional the construction may consist simply in filling the track with ballast, level with top of rail, outside and inside, leaving proper flangeways inside the rails.

Deep flangeways at crossings give considerable trouble in winter time. Mud or snow which gets packed into these spaces and frozen is difficult to pick out, and if it is not removed it is liable to be crowded under the planks or against them so tightly as to start the planks loose. To obviate this difficulty the bottom part of deep flangeways is sometimes blocked with filler strips of wood, and in other cases the inside planks are laid against the web of the rail and cut out to desirable depth for the flangeways. A wood bottom for the flangeway helps the matter but very little, however, as mud and ice will freeze to it tightly and must be chipped off in small pieces when clearing out the space. On a number of roads, including, among others, the Chicago, Rock Island & Pacific and the Toledo, Peoria & Western, the flangeway at highway crossings is formed by laying an old rail on its side inside each traffic rail, with its head against the web of the traffic rail, as shown in Fig. 39. The upturned flange of the rail so laid forms the inside of the flangeway and a backing for the plank. If the space between the flangeways is to be paved this upturned flange should be placed as nearly vertical as is practicable, so as to permit the paving blocks to be fitted snugly against it. At each end of the crossing this flange is bent inward, toward the center of the track, to form a flare for the flangeway. On most roads where the flangeway is formed in this manner the rail laid on side is not made fast in any way except as shown in the figure. Its head lies under the head of the traffic rail and the planking is fitted tightly against its base, holding it securely. On some roads, however, about 6 ins. of the flange and web at each end of the rail are cut away and the projecting piece of the head is drilled and bolted to the web of the traffic or running rail. On the White Mountains division of the Boston & Maine R. R. it is the practice, where a joint comes in the running rail at the crossing, to drill holes directly through the head, web and flange of the flangeway rail that is laid on its side and use long bolts, the flangeway rail serving as the inside splice bar.

If the railway company has old iron or steel rails to spare the flangeway guarded by a rail laid on side is undoubtedly the cheapest plan in the end. The arrangement certainly answers the purpose well. There being no deep rut to hold mud, dirt or snow, such material is cut up by the wheel flanges and loosened. To clean out such a flangeway it is only necessary to draw the point of a pick, or shove the point of a bar along the bottom, and then to scrape away the loosened material with a shovel or brush it aside with a broom. By the use of salt such a flangeway can easily be kept clear of snow and ice.

The practice of forming the flangeway by laying an inside guard rail on its base, or workwise, is objectionable for two or three reasons. In the first place, the under corners of the rail heads, in the flangeway, form a dangerous trap for horses' feet. If the toe calk of a horse's shoe catches under the rail head in a flangeway of this kind the horse is liable to be thrown or have his hoof torn loose; or if a horse becomes frightened and attempts to turn around on the crossing there is danger of catching a wagon wheel. At crossings of this kind it is usual to keep the flangeway filled with dirt up to the level of the under sides of the rail heads, but unless the material is compacted very hard the danger referred to is not entirely removed. And then, again, as such a flangeway widens out below the rail heads and has no well defined bottom it is difficult to

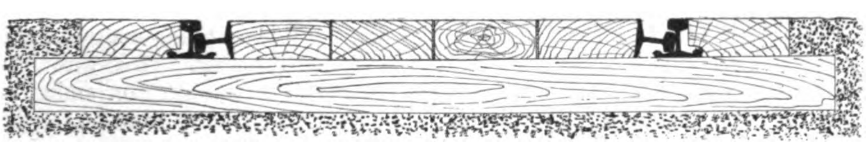


Fig. 39.—Highway Crossing Flangeways of Old Rails.

pick out and keep clear. A common form of crossing of this class, known as the "skeleton" crossing, has two guard rails laid inside the running rails to 3-in. flangeways for such distance as is desired for the length of the crossing, and then each guard rail is bent inward at an angle of 45 or 90 deg. to meet the end of the similarly bent opposite guard rail, in the middle of the track. The enclosed space is usually filled with broken stone or slag, covered with a top dressing of screenings or cinders.

Owing to the necessity for tearing up plank in order to raise the rail, low joints in highway crossings usually get less attention than they do elsewhere, and so when it can be avoided crossings should not be located to bring a joint within the planking. Of course this rule is more easily followed on square-jointed than on broken-jointed track, but by laying 60-ft. rails at all ordinary crossings there will usually be no difficulties in this respect. Even if a shorter rail is standard on the road it would pay to use rails of this length at the crossings. When building track it is an easy matter to carry enough extra long rails to lay the crossings, and on old track they may be laid gradually in the course of rail renewals. In the latter case the best plan is to order enough long rails to lay all the crossings on the division or stretch of track whereon rail renewals are to be made during the year, and then distribute all these rails at one time, before the rails to be laid in the ordinary course of renewals are delivered on the track. Where a joint does come in the crossing, the plank which is placed next the rail on the outside should be boxed out for the splice and bolts, rather than beveled off underneath, so that the nuts can be got at when loose, without taking up the plank. But if the rail be high enough to permit the wheel flanges to clear the nuts, it is better at crossings to put the bolts through the splice from the outside, so that the nuts come on the gage side of the rail and in the flangeway.

Railway companies are concerned in the lay of the land in the vicinity of road crossings at grade. Crossings in a cut or on or near a curve should be avoided in every case possible. The grade of the highway on the approaches to the crossing is one of the important considerations, for if heavily loaded teams get stalled on or near the crossing they are in danger of being struck by trains. In light cuts where the road must be depressed to meet the track at grade it should be graded back to a rise which does not exceed 1 in 10. On some roads the rules limit the rise to 1 in 6, but the safest plan to follow in any case would be to grade the road to the level of the crossing for the length of a wagon and

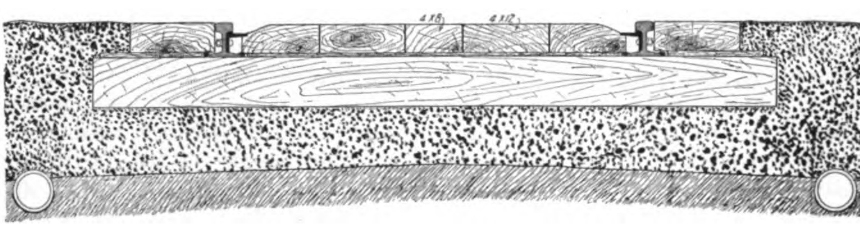


Fig. 41.—Highway Crossing with Detachable Tram Bars and Tile Drains.

team, and a few feet further, each way from the track; this arrangement gives a team a chance to pull quickly over the crossing. It is also important to limit the grade of highway approaches to crossings on embankments. The standard rules of the New York Central & Hudson River R. R. require that the grade of highway approaches shall not exceed 6 per cent and of farm crossing approaches 8 per cent. Where a highway runs up hill approaching a crossing the dirt will sometimes work down from the outside edge of the outer plank and cause a jolt to wagons. This difficulty may be overcome by filling in the road to a level with the top of the crossing plank, or slightly sloping from the track, for some distance out. Where there is a steep slope right up to the crossing plank the wagon wheels and horses' hoofs will usually wear away the dirt, so that a vertical lift of several inches is necessary to get the wheel onto the crossing. Where such conditions are found a heavily loaded team is liable to be stalled on the crossing. In some states railway companies are obliged to construct and maintain all that portion of the public highway which lies between the lines of the right of way at crossings.

The high speed of modern passenger trains makes it desirable to eliminate grade highway crossings at every opportunity. On many of the larger railway systems overhead bridges or subways are being substituted for crossings at grade, on a large scale. Generally speaking, accidents at grade highway crossings are too numerous on all railways, but in building independent lines where only light traffic is in prospect it is practically out of the question to propose the abolishment of the grade crossings: only the most prosperous railways can meet the expense. There are many situations, however, where, by diverting and consolidating highways, the number of crossings in a locality may be decreased, one crossing being made to carry the travel formerly passing over two or more that were near together. Moderate expenditures for such improvements are sometimes paying investments.

Crossing Drainage.—Ditches should not be discontinued at, or obstructed by, road crossings, but should be carried under the road by box culverts or vitrified or iron pipe. It is a good plan in any case, whether there is a ditch at either side of the crossing or not, to lay some kind of a drain near the ends of the ties to carry off the water. Farm tile, laid as in Fig. 41, answers well for this purpose; and small box drains or trenches filled with cobble stones are largely used. At crossings which come in a cut, or wherever water is liable to settle around the crossing, some kind of drain should always be provided. In the case of double track a tile or other drain should be laid along the midway, under the crossing, and then turned under one of the tracks into the ditch. No little difficulty in maintaining track at road crossings arises from the practice of grading highways up to a point higher than the roadbed close up to the ends of the ties, thus forming an obstruction which prevents the water from draining freely away from the track. Sketch "A," Fig. 41A, shows a mistake frequently found, where the track and ballast are made to lie in a trench which is formed by grading the road up to the level of the top of the rail, close up to the track. From this trench there is no side drainage. Sketch "B" shows a method of drainage recommended by a society of section foremen of the Chicago, Milwaukee & St. Paul Ry. for such places. The space for a distance of 5 ft. outside the ends of the ties is excavated to a slope starting 12 ins. below the ties at their ends and running to a depth of 18 ins. in the distance of 5 ft. This ditch is filled in with cobble stones, permitting not only the drainage of surface

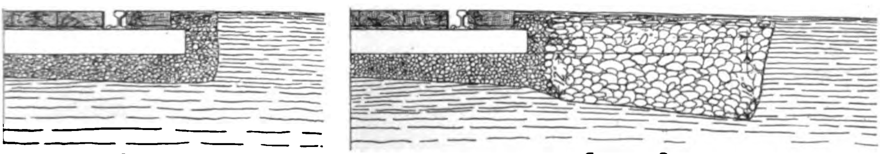
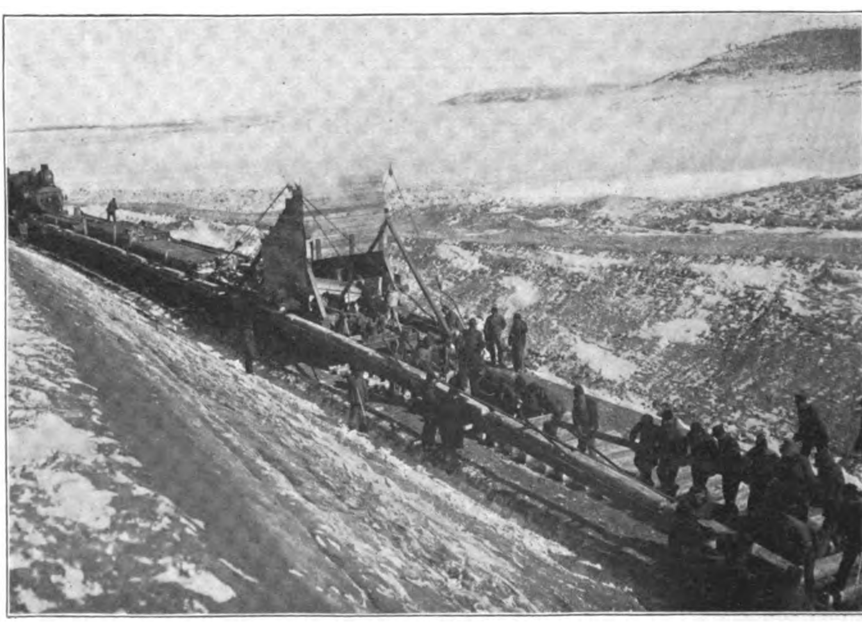


Fig. 41 A.—Drainage for Track at Highway Crossings.

water sinking into the track, but also catching and diverting water which otherwise might run upon the track. The highway should, of course, slope away from the crossing at a slight grade. To facilitate the drainage at crossings they should be filled in with a good quality of ballast. To overcome the objectionable effect of "churning," the crossings of the Chattanooga, Rome & Southern R. R. (Central of Georgia system) are filled in with washed gravel.

Construction in Paved Streets.—In some of the eastern cities a built rail of girder shape has been gotten up to conform to local ordinances requiring that steam roads shall use girder rails in tracks which follow the streets for some distance. The design is formed by bolting a tram bar to the ordinary T-rail. This bar somewhat resembles an angle bar bolted to the rail in an inverted position, and is illustrated in Fig. 40 (shown with Fig. 33). It is attached to the rail by drilling holes through the web about 3 ft. apart and bolting. The expense of putting it on is small, and it is good construction for crossings. No trouble arises from joints, since the tram bar takes the place of a splice bar on its side of the rail, it being necessary to simply drill it for the bolts, either before or after it is in place. At a crossing provided with flangeways of this kind (Fig. 41) the planking or paving is beveled off on the top edge and laid up under the tram. As there is nothing to confine dirt and other material falling into the flangeways the wheel flanges cut it up and shove it aside, and but very little cleaning is required. The standard track of the New York Central & Hudson River R. R. for stone-paved streets is laid with these detachable tram bars.

At crossings in streets paved with deep blocks of stone or other material it is necessary to lay the ties low, in order to make room for the pavement. This may be done by supporting the rails directly on chairs spiked or lag-screwed to the ties, but for long stretches of track laid in streets paved with deep blocks it is better practice to use rails of special girder section, which are usually about 9 ins. deep. The paving blocks outside the track are sometimes laid directly against the head of the rail and ¼ in. below the top of the same, but if the track settles or some of the paving blocks work up the car wheels will bear upon the paving and loosen it. The paving is also liable to be loosened by the undulation of the rail. To provide against trouble of this kind a strip of timber may be interposed between the rail and the paving. For this purpose a 4x6-in. treated timber, laid on edge, is recommended. By cutting out at the top corner for the rail head it may be fitted against the web, and it should be laid to bring the top surface ¼ in. below top of rail. Track that is laid in paved streets or in long highway or street crossings should be constructed of materials of more than ordinary durability substantially put together. Improvements in these respects involving only moderate expenditure would be found in the use of creosoted ties and tie plates, with tile drains parallel with the track. A type of concrete foundation used by the Pere Marquette R. R. for track in the streets of Bay City, Mich., is described in § 169, Chap. XI.



Roberts Track-Laying Machine in Action.

CHAPTER IV.

BALLASTING.

32.—Construction trains usually begin running over the track as soon as it is laid, but such usage does not improve its condition, and the sooner it is ballasted, therefore, the better. As a general proposition track is better for having a depth of at least 12 ins. of ballast underneath the ties. Where the roadbed is a fill or wherever it is dry and compact, more than this depth is not needed, for even 5 ins. will maintain the track in fair condition in such places; but it ought not to be less than 5 ins. in depth in any case, except where the roadbed is gravel or some other material which answers well for ballast of itself; in fact, 8 ins. is considered the minimum allowable depth for good practice. The least depth of ballast which will distribute the pressure from the ties uniformly over the roadbed is about 12 ins. for broken stone and presumably more for gravel. In experiments made in Germany by Herr Schubert, with broken stone ballast 11¾ ins. deep under the ties, on a roadbed of plastic clay covered with a 2-in. layer of sand, the clay surface remained even when the load was applied; but when the layer of ballast was shallower than the stated depth the clay directly under the ties was depressed more than elsewhere. The load applied was 57 lbs. per sq. in. of tie bearing surface.

When it is necessary to economize in the use of ballast it is better practice to arrange the quantities to suit the conditions than to cut down the allowable depth and make it uniform at all places. As a rule more ballast is required in cuts than on fills, especially in wet cuts. In clay cuts the ballast should be at least 18 ins. deep under the ties, so that the pressure from the traffic will be uniformly distributed over the roadbed. While broken stone is good material to distribute pressure, it does not work well on a clay bottom or on a wet roadbed, because clay becomes plastic when it gets wet and the softened material will work up through the voids between the stones. The most satisfactory material to use in such places is a bottom layer of engine cinders 12 ins. deep, covered with 6 to 12 ins. of broken stone or gravel. As already stated, flat stones are sometimes used to cover a soft bottom, but cinders are just as good, or even better, and in any case it would be a good plan to use a layer of cinders over the flat stones, to prevent plastic material from working up. In cuts through hard rock the roadbed is not usually graded to a uniform surface, and full depth of ballast is necessary in order to properly bed the ties over the high points. It is good practice to excavate rock cuts a foot below the profile grade and then build up to sub-grade with broken stone, leaving proper side ditches. Above this the depth of ballast may be regulated to suit the conditions of the locality.

There are but few railroads in this country whereon the standard depth of ballast under the ties, for ordinary conditions, exceeds 12 ins. The most usual depths in the standard specifications for ballast are 12 ins., 10 ins. and 8 ins., in the order named. In the standards of 50 of the representative railways of the country a depth of 12 ins. is found 20 times, 10 ins. 14 times and 8 ins. 12 times. The least standard depth is 4 ins. and the maximum 24 ins., in a few instances. In this connection, however, it is well to again bear in mind that the fashion of "standards" is contagious, and the amount of ballast which the section foremen actually get under their ties may not always measure fully up to the chief engineer's "standards." It is true, nevertheless, that better ballast and more of it is being used than formerly.

The use of ballast in raising track to the original grade on settled embankments and to a uniform grade across sags may, of course, increase its depth considerably beyond the standard specification. For this reason many think that it is extravagant of material to put track up on first-class ballast before the banks have become well settled. The idea is worth careful consideration. The plan would be to surface the new track with dirt on or but little above the sub-grade. As dirt ballast is very cheaply obtained and handled, and can be dressed to keep water out of the roadbed to a large extent, the use of the same for two or three years should enable the embankments to settle compactly without becoming plastic in the center and "pushing out." After that the dirt can be removed from between the ties, the top of the roadbed dressed to the desired slope in its compacted condition, and then the track can be raised and ballasted with gravel, broken stone or other good material in just such quantities as are desired to suit the various requirements of the roadbed in cuts, on embankments, etc.

Surfacing consists in placing the top of rail to an even line. Ballasting consists in filling the space underneath the ties with ballast, making it as compact as is practicable, and filling the space between the ties. Where suitable ballast material can be obtained along the line, close at hand, it should be hauled out with teams and a layer of it, within about 2 ins. as deep as it is intended to have the ballast, spread over the roadbed and leveled off smoothly before the track is laid. As a general thing it can be placed more cheaply in this way than by hauling it with the train and shoving it under the ties after the track is laid, because then the track must be raised so much the higher. There is also a further advantage in that, from being driven over by teams, the bed of ballast becomes quite compact, whereas ballast placed under the ties after the track is laid will always settle a good deal at first. On dry roadbed it is quite customary to first place a layer of stones broken to the size of cocoanuts, or a paving of flat stones laid shingle fashion (standing at an angle of about 45 deg. and leaning against one another), and then lift the track 6 ins. when placing the gravel, broken stone or other ballast. Track laid on loose rock not broken up should be chinked in or roughly blocked at the ends of the ties before the outfit train is allowed to run upon it. This work is quickly and easily done, as the stones for blocking are close at hand. Where gravel ballast varies in size the coarser material should be put underneath. Sometimes in working out a gravel bank the run of the strata is such that the coarse material may be separated from that of finer quality and taken out first. In such event the track should be raised to grade in two stages, using the coarse gravel at the first lift (say 6 or 8 ins.), without dressing off, and then top out with the finer material when the track is surfaced to the final grade line. It is advantageous to give the track a little time to settle before raising it the second time, for the consolidation of ballast in any considerable depth must come about by settlement under the traffic.

33. Rail Grade Stakes.—The grade for top of rail in ballasting is indicated by stakes about 4 ft. from the rail at one side of the track, opposite every full station, and wherever there is a change of grade. These stakes are set after the track is laid. The stake is driven or sawed off to bring its top to grade. If the foreman in charge of the work is experienced at raising track it is useless to set stakes closer than 100 ft. apart, except where there is a change of grade; and there is no necessity, either, for setting stakes both sides of the track.

Vertical Curves.—Where a considerable change of grade occurs stakes should be set for a vertical curve. The length of this curve should be proportional to the amount of change in the grade—20 to 50 ft. for each one-tenth of one per cent change being customary practice. Engineers should explain to foremen who are unacquainted with these curves their nature, so that they will get the rails to a curved surface instead of making of them a series of grades. Stakes should be set every 50 ft., or even closer, always putting a stake at the middle point of the curve—that is, at the vertex or point of meeting of the two grade lines—and then they should be spaced equally each way from this point to the ends of

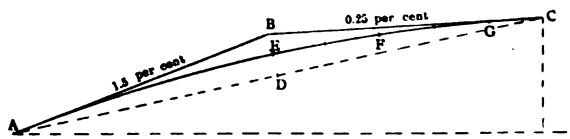


Fig. 42—Vertical Curve.

the curve, without regard to the established stations of the center line of the track. Instructions for setting these stakes are given in field books, but for the benefit of trackmen an example of the kind will here be considered. Referring to Fig. 42, let *A B* represent a grade of $1\frac{1}{2}$ per cent and *B C* a grade of $\frac{1}{4}$ per cent. The change in grade at the point *B*, the vertex, is then $1\frac{1}{4}$ per cent, and if 40 ft. be selected as the length of the curve for each tenth of change the curve will then be 500 ft. long and run 250 ft. each way from *B*. Set a stake then at *B* and every 50 ft. (or some multiple distance of half the length of the curve, not exceeding 50 ft.) each way, it not being necessary to designate the stakes by marks or numbers any more than to show that they are rail grade stakes. The point *D* is half way between *A* and *C* on the straight line *A C*, and its elevation is readily found from the known elevations of the points *A* and *C*, being higher than *A* by half the difference of level between *C* and *A*. Of course *B* is not vertically over *D*, but no perceptible error is made by assuming it to be such. The point *E*, on the proper grade for the curve, is half way between *B* and *D*; and any point between *E* and *C*, or between *E* and *A*, on the curve, is at such a distance from *B C* or *B A* that its ratio to the distance *B E* equals the ratio between the square of the distance of the point *C* or *A* and the square of the distance *B C* or *B A*, according to which side of *B* it happens to come. For instance, the distance of the point *F* below the line *B C* (call it x) would be found by the equation

$$\frac{x}{BE} = \frac{(FC)^2}{(BC)^2} = \frac{(\frac{3}{5})^2}{(^5/_5)^2} = {}^9/_{25}\text{; or } x = {}^9/_{25}\,BE.$$

In the same manner the distance of the point *G* from the line *B C* would be $(\frac{1}{5})^2\ B\ E = {}^1/_{25}\ B\ E$. Where the grades meet in a sag the curve is located above the two grade lines, of course, and the distance of any point on it from one of the grade lines is found in the same way as has just been described. The distance thus found is additive and gives the same result as though the figure (Fig. 42) was inverted. It is usual to grade the roadbed to conform to the same vertical curve, but more care should be taken in setting stakes for the rail grade than is necessary for the sub-grade. Foremen are not apt to run in a vertical curve very well by the eye; that is, to surface the track well at such a point without stakes. A change of grade should not occur on a horizontal curve in the track if it can be avoided.

Mr. Wellington's rule for the length of vertical curves is based on the following consideration: "The rate of grade on which the head of the train stands must in no case exceed that on which the rear of the train stands by more than the grade of repose* of the last car." For sags Mr. Wellington's rule is: "The curve should be 400 ft. long (that is, 200 ft. on each side of the vertex) for each tenth in change of rate of grade, making the change in rate of grade per station not over .025 per station, if all possibility of bringing the draw-bars of any part of the train into compression while passing over it is to be avoided. With half this length of curve, which is considerably more than is usual in laying out vertical curves, all danger of 'taking out the slack' in the front half of the train, where there is most danger of breaking in two, will be avoided." It is thus seen that the idea in the mind of the author quoted was to so limit the change in rate of grade that in passing over sags the cars in the rear of the train would have no tendency to run into those in front. But since the long coupling of former days has gone out of use there is now far less cause for trouble in sags, and accordingly vertical curves are now made much shorter than this rule requires. To always follow this rule would give some lines a very sinuous appearance, indeed, while in many cases it would be impracticable.

The best method of making the transition between grades of varying inclination was one of the subjects reported upon at the sixth session of the International Railway Congress, held in Paris in 1900. As a great deal of mathematical learning has been brought to bear on this question in times past the information produced by the reports presented is of particular interest. One of the reports was prepared by Mr. Van Bogaert, chief engineer of the Belgian State Ry., and covers the practice of 67 railroads in Europe, Great Britain, the British colonies and the United States. The report reaches the conclusion that, from theoretical considerations and from practical experience, a vertical curve of 16,000 ft. radius is quite sufficient to prevent severe jerks in the draw-bar pull resulting from sudden change in the tractive effort of the locomotive due to a change of grade even as great as 2 per cent. A sag between two grades is not considered dangerous even if the connecting curve is of a radius considerably less than 16,000 ft. This is the radius (5000 meters) adopted by a large number of roads, none of which reported trouble as having arisen from the radius of the connecting curve being too short. The minimum radius prescribed by the German Railroad Union is only 2000 meters (6500 ft.). This is the radius in use on a number of European roads in hilly country, with results reported to be entirely satisfactory. In sags between opposing grades the tendency of the cars is to bunch together and drive the buffers in, but on vertical curves of

*By "grade of repose" is meant the minimum grade upon which a car will start itself without assistance. This is not the same as the minimum grade upon which a car will keep moving after it is once started; such is not nearly so much as the grade of repose. The grade of repose (proper) is about 0.4 per cent and the grade on which a car will continue to move after being started is about 0.3 per cent for box cars, in each case, depending always on the amount of journal friction.

any considerable radius such action takes place gradually and no harm results. On summits between opposing grades, or where the grade changes from a rise to a level or from a level to a fall, the draw-bar pull is subject to sudden changes, at high speed, and break-in-twos occasionally take place, although the jerk at such points is nothing nearly as great as is liable to happen from the action of the brakes. The report recommends that for changes of grade greater than 1 per cent, passing from a rise to a level or from the level to a falling grade, or over a summit between opposing grades, it is advisable to ascertain by means of a dynamometer car whether the curve used in any case has a radius of sufficient length to prevent sudden jerks in the draw-bar pull. For changes of grade less than 1 per cent the report maintains that the question is not of any importance. It is not desirable, however, to have a change of grade occur where there are horizontal curves of short radius.

Replies to a list of questions making inquiry for the details of practice on the different roads indicate a great diversity as to the form of curve used. Although the circular arc is the form most commonly found, nevertheless a considerable number of roads use parabolic curves, some roads introduce a piece of level track at the summit of opposing grades, several roads make the transition by means of a series of inclines, each of 20 to 30 ft. length and changing one tenth of 1 per cent. On the other hand, some roads having grades as steep as 2½ and 3 per cent do not use vertical curves connecting changes of grade. The radii of vertical curves used on different roads, as noted in the report, vary from 3000 to 33,000 ft. The practice of running out the vertical curves also varies greatly. On many roads there are no definite rules regarding vertical curves, and in surfacing the track reliance is placed upon the judgment and the eye of the section foreman, who puts in such a curve as he thinks will answer the purpose. Of course the most careful practice is to establish the curve by setting grade stakes instrumentally. In some cases the roadbed is graded to the vertical curve, while in others the curve is introduced only as the track is ballasted, the grades in the roadbed, in that case, continuing to an apex or to the point of meeting. In some cases where opposing grades are steep, however, as at a summit, the roadbed is graded level at the summit and the curve is introduced when the track is being ballasted; in other cases the roadbed is graded to the curve only where the difference in the grades amounts to as much as 1 per cent.

The facts set forth in the report show that general practice in the use of vertical curves is much simpler than some theories would lead one to suppose. For convenience of surfacing the track the curve should be as short as will conduce to safe operation. A curve of 16,000 ft. radius connecting grades where the change amounts to 2 per cent is only 164 ft. long each side of the vertex, or 328 ft. in total length. To follow some rules requiring a curve of very long radius, on roads where the grades are much broken, there would not in some cases be room enough between the points of change to get in the curve. It seems to be proven in practice that vertical curves of considerable length are not required where the change in rate of grade does not exceed ½ of 1 per cent.

34. Raising the Track.—A jack is a better tool for raising track than a lever, because it requires only one man to operate it, whereas a lever usually requires three or more; the jack can also lift through a greater vertical hight without changing, and it does not throw the track out of line so much as when raising with a lever. If the roadbed is soft, so that the jack sinks in too much, it may be stood upon a piece of plank. Using the level board, the rail is raised to surface opposite each rail grade stake, and then at the joints and centers, blocking them to place, or shovel-tamping if the ballast is at hand. It is an advantage to have ballast on hand in sufficient quantity to tamp the tie ends, because blocking will settle when the train comes on, and the track will have to be raised again; besides, it is not altogether desirable to leave blocks, stones, etc., under the track so near the bottoms of the ties. With rails of heavy section the stiffness of the rail will usually hold the quarters to surface if the joints and centers are supported. On track laid with rails of light weight a quarter now and then will sag and require raising to surface. In a high lift light splices are in danger of being bent by taking hold of the rail at the joint. It is better in a case of this kind to take some point 2 or 3 ft. to one side of the joint as the raising point. Track usually settles as soon as the jack lets go, and allowance should be made accordingly. It is a good plan to raise every joint somewhat higher than the point to which it would naturally settle back, so that it will stand striking down. The usual arrangement is to have a man carry a 16-lb. sledge along and strike down on the tie tamped. In this way a good surface can be had without taking so much pains with the raising, and the ballast under such ties gets hardened to a considerable extent by being struck down.

It is well to raise and hold the rails on both sides to surface before tamping the ends of the ties, because where one rail has been raised and the tie ends have been tamped, when it comes to raising the rail on the opposite side the rail first raised will rise with it an eighth to a quarter as fast and leave the ties which have been tamped bearing only at their ends, with a clear space under the tie at the rail seat. The side last tamped will then hold up better than the side tamped first, and the track will settle more on one side than on the other; but this is not liable to happen where neither side is tamped until after both sides have been raised and held. Unless the side first raised be blocked, and that directly underneath the rail, it will rise a little with the second side when it is raised, as just explained, and after the track is leveled across or elevated it will be somewhat higher than the grade stakes. There is no objection to this excess, because it provides an allowance for settlement and does not usually leave the surface of the side first raised uneven; should it do so occasionally, a few strokes from the sledge on the high ties will usually put it right. Some make it a practice to set the jacks outside the rails and raise both sides of the track at the same time. Where the lift is high this is a good plan.

The man who sights the rail should be at least 60 ft. back of the point which is being raised, so that his eye can catch a good stretch of rail between. It is well to designate each point which is raised opposite a grade stake by placing a pebble or chunk of dirt on the rail, for it is an aid in sighting other points on the rail with reference to it. One man can sight for two jacks—one at raising joints, the other at raising centers. About the utmost speed attainable in raising track at one place would be had by using five jacks; one crew with jack and level board could put both rails to grade opposite grade stakes; a man behind, sighting for two jacks, could follow and place one rail, that is one side, to surface; and behind him, on the opposite side, a crew with jack and level board could raise the joints, and another jack with a man to sight for it could be used in putting up the centers. The best sighter should be put on the side which is in the advance. It requires a little genius as well as judgment to sight rails well and rapidly. Young or inexperienced foremen use various devices as an aid to sighting the rails. One of the simplest of these is three blocks, all of the same thickness or hight. Two of the blocks are placed on the rail at points where it is at the proper hight, at any convenient distance apart within sighting range; the third block is placed upon the rail at the point which is being raised, and when it is brought up into the line of sight with the other two the rail at that point is at the proper surface. Another device consists of sighting blocks and boards, worked on the same principle. There is a thin plank or board usually painted white, with a black stripe running longitudinally its whole length. The board has L-shaped irons or feet to steady it in an edgewise position, and when the track opposite a grade stake has been raised and blocked or tamped to surface and leveled, this board, called the "hight board," is placed to stand edgewise across the rails; or it may be set at proper hight, across the track, on heaps of ballast in advance of the work. By means of two other boards or blocks, called "sighting boards" or "sighting blocks," as the case may be, one placed on the rail at the observer (where the track is in surface) and the other at the point where the track is being lifted, the rail is sighted to surface. The thickness or hight of the "sighting" boards or blocks corresponds to the hight of the stripe on the "hight board." Foremen experienced at sighting rails can get along without these devices and do the work just as well and just as rapidly. In fact, some foremen, in raising new track or any track where the top faces of the ties are clean, do not sight the rails at all, but stand back a little way in the middle of the track and judge of the rail surface by the appearance of the ties. When the rails are out of true the ties appear to form the elements of a warped surface. On curves the rails are sighted along the inside of the curve.

Track on tangents should be raised and tamped level transversely. There are those who claim that a train will run more steadily on straight line if the rail on one side is about $\frac{1}{4}$ in. lower than the other, than it will on track which is level transversely. This claim is based on the idea that the wheel flange on the lower side will follow the rail instead of moving first toward one side and then toward the other, as it does on track which is level transversely. But the coning of the wheels would not in all probability allow this steadiness of movement on straight line; and if it did, more power would be expended in hauling the train, because if the same wheel flange followed one rail all the time, either one or both wheels would have to slip a little almost constantly.

In ballasting new track it is desirable, especially when working a large crew, to have the track where raising is in progress entirely free from passing trains. In case the ballast must be hauled from the rear the best plan, if practicable, is to first unload ballast along the track for several miles in sufficient quantity to tamp the ties outside the rails; on fills where the track is to be raised 6 ins. or higher there is not usually room for more material than this. Then everything is ready to begin with part of the crew to raise the track and tamp the ties outside both rails; this will hold up a train without settling to hurt, and the train should follow to haul what ballast is needed to complete the work. The remainder of the crew should follow the first party and tamp the ties between the rails, line the track and fill it in.

35. Tamping.—Except where broken stone or slag is used for ballast the shovel is the best tool for tamping new track. Tamping bars are not effective in such work. The tamping bar is intended to be used only where ballast can be confined in a small space, such as is found between the bottom of a tie and a hard bed, when the lift is small. In raising new track, where the lift is usually several inches, the ballast must necessarily be put in loose; and it can become hard and compact only after time and by pressure from trains running over it. The range of action of a tamping bar is only an inch or two in depth below the bottom of the tie at the most, and consequently it is a waste of time to attempt to harden several inches of ballast under the tie with such a tool when the ballast between the ties is in a loose condition. The shovel does just as good work and is far more rapid. In shovel tamping, the gravel or other ballast is first shoved under the tie with the shovel blade, and then crowded, the latter effect being produced by putting the foot on the shoulder of the blade and driving it under the bottom of the tie, at the same time prying backward a little on the handle, thus enabling the lower edge of the blade to pry forward and crowd. Before placing the foot upon the blade, ballast should be filled in between the ties as high as an inch or two above the tie bottoms, so that a fulcrum may be had for the back of the shovel blade to pry against. The thin edge of a shovel blade, even when new (being only about $^3/_{32}$ in. thick) is not worth much for a rammer; it is, therefore, the prying and ramming combined which crowds or tamps the ballast under the tie, but principally the prying. This is the reason it is so important that ballast between the ties should all the while be kept somewhat higher than their bottoms, and that the edge of the shovel blade should penetrate under the lower corner or edge of the bottom face, instead of against the side of the tie. It is somewhat difficult to describe just exactly how shovel tamping is rightly done; it is easier done than said. It is work which requires judgment, and that must be acquired by experience. New men seldom if ever do it properly on the start. An intelligent man may soon learn it, but some never do.

In starting out at tamping the foreman, who by all means should at some time have worked at shovel tamping himself, should take a shovel and show each man individually how it is done. After he has gone through the crew in this way he will usually have occasion to come right back and, with as much emphasis as possible, inform about 49 out of every 50 men that they are not doing it properly; for, invariably, instead of tamping the ballast *under* the tie, nearly all will be found trying to pack it *against the side* of the tie. More money is wasted in paying for poor tamping than for all other poor work on track put together. The man in charge of a surfacing or ballasting crew must therefore be vigilant. Men should be given to understand that as soon as a tie is properly tamped the work on that tie should cease, since there is not the slightest necessity for tamping against the side of it; that is to say, above the edge of the bottom face; that as soon as one is through tamping under the bottom of one tie further effort can most profitably be expended under the bottom of the next tie ahead; that to the laborer the physical exertion must, in any case, be the same whether he remains hopping up and down on his shovel, spudding it against the side of the tie, or whether he moves to the next tie ahead as soon as the tamping of the tie is properly finished. The foreman's command of language cannot be used too vigorously in bringing these points to the notice of his men. Shovel tamping when well done will give good results, but when poorly done it is much expense laid out for little or nothing in return. Foremen should not forget this.

Most kinds of dirt ballast cannot be well tamped with the shovel blade. Cast ends are sometimes provided for shovel handles, so that the tamper may take the edge of the blade in his hand and use the handle as a rammer, and in some kinds of dirt ballast they do pretty good work. A tool called a puddle is sometimes used for this purpose. It resembles very much a tamping pick with the pick end of the tool cut off near the eye.

Stone and slag ballast are tamped with tamping picks. Each tamper works by himself, stooping over the tie and driving the rock into the space underneath it. In order to do this work uniformly, more or less care must be exercised, for, if not mindful, one may, in striking with a tamping pick, easily wedge parts of the track up above its proper surface. The material is first thrown into the track loosely and pushed under the ties with shovels, and then thoroughly packed with the tamping picks. After a few days the track should be carefully resurfaced, taking out the rough spots, tamping the raised ties and filling in and dressing off. As already stated, rock to be broken for ballast is sometimes thrown into the track and broken up there. This is not a good plan to follow, however, since the ballast is liable not to be broken finely enough to the proper depth, unless the rock be thrown in a piece at a time; it gives the men a chance to break the material finely on the top and leave larger pieces underneath where they cannot be seen. The ballast, if broken on the spot, ought, therefore, to be broken up on the shoulder, outside the track. It should be thrown in with forks rather than shovels, since with the latter it is difficult to handle rock ballast lying on the ground without taking up some dirt with it; and of course it is desirable to keep rock ballast clean, in order to prevent the growth of vegetation and the churning of the ties.

Shovel tamping is done on both sides of the tie simultaneously. Outside the rails two men work together, on opposite sides of the same tie; between the rails four men—two on each side of the tie—usually tamp together. Ties should be well tamped directly underneath the rail seat. This can always be done to best advantage by getting the tool in there at the start. A shovel blade must be thrust in cornerwise in order to do it, and such cannot be done after the tie has already been tamped farther out toward the end; or farther in toward the middle, if tamping be done inside the rails. When tamping either outside or inside the rails one should aim to tamp the tie directly underneath the rail from that side. It is an easier matter to tamp the ties at this point when using a tamping bar or tamping pick than when using a shovel. When tamping new track for the first time, the middle of the tie may, without ill effect, be tamped as firmly as the ends, but after that the middle should never be tamped quite as solidly as the ends.

36. Ballast Cars.—In handling ballast for new track two kinds of ballast car, or a car which combines the typical features of both kinds, can be used to best advantage. Reference is intended to cover cars which can be unloaded from the side and those which can be dumped from underneath. The latter saves the expense of once handling part of the ballast, for otherwise it must be cast into the track from the outside. As is well known, cars are made which combine these two features in one. While cars which dump by careening to the side may be made to do good work at filling in a trestle, they do not answer well for dumping ballast, because the momentum with which it leaves such a car will sprawl it over the shoulder and down the slopes, on fills of ordinary width, much being thereby wasted; and again, wherever a car is dumped a whole load must go, whether all is needed there or not. For unloading to the side it is more economical of ballast and more convenient to unload off ordinary flat cars by hand than to use careening side-dump cars. The cheapest method of unloading flat cars, however, and the one most extensively in service, is by the use of the unloading plow and cable. The various devices of this kind and their manner of operation are described and illustrated under the subject of "Handling Ballast and Filling Material," § 148, Chap. X.

A very common type of side-dumping ballast car is built on the gondola style, with a crowning floor (running to a peak in the middle of the car) and swing side doors hinged at the top. When the doors are unlatched the ballast slides out by gravity, close by the side of the track. The Pratt side-dumping car, in use on the New York, New Haven & Hartford R. R., is an 8-wheel car of about 25 cu. yds. capacity and 28 ft. length inside. The sides of the car are divided horizontally into two parts, or with one swinging door above another, so that, if desired, only half of the load on each side of the car need be discharged at one dumping. The upper door is released first, and if it is desired to carry the remainder of the load a car's length ahead, the lower door is

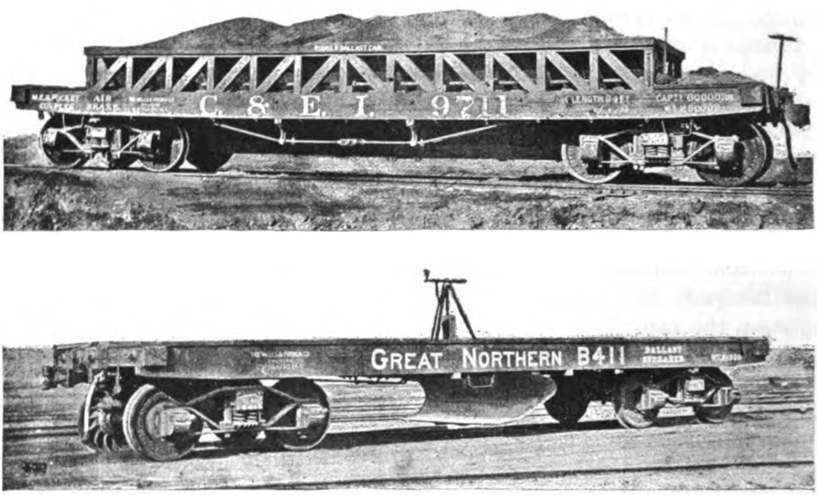


Fig. 43.—Rodger Ballast Car and Spreader.

held closed until the car is moved, when the remainder of the load is dumped. The Womelsdorff gondola ballast car, used on the St. Louis Southwestern Ry. of Texas, for cinders, has a deck inclining each way from the middle, and a side drop bottom. This drop bottom is in four sections on each side of the car, and consists of wrought iron plates $^5/_{16}$ in. thick and $2\frac{1}{2}$ ft. wide, hinged to the bottom edge and inside face of the intermediate sills. Two of the sections or aprons are each $12\frac{1}{4}$ ft. long and the other two are each 4 ft. 2 ins. long. The drop aprons are held in position by chains winding upon a $1\frac{1}{4}$-in. shaft extending the length of the car (inside) at the top of each side and operated by brake wheels on vertical shafts connecting by means of worm gearing at the top, while at the bottom the wheel shaft has the ordinary ratchet and pawl. The aprons drop through an angle of about 40 deg. and permit the ballast to slide freely from the car, under the side sill, onto the shoulder, close by the track. The car is $34\frac{3}{4}$ ft. long over end sills and 8 ft. $10\frac{1}{4}$ ins. wide.

For unloading ballast between the rails, cars are made with hopper bottoms. A well-known car of this type is the Rodger ballast car, shown in Fig. 43, as constructed by the Chicago & Eastern Illinois R. R. The length of the car is 32 ft., the width 8 ft. 9 ins. and the hight of the top of the car above the rails 6 ft. 1½ ins. The capacity of the car level full is 14.6 cu. yds., and when heaped 18 to 20 cu. yds.; as it appears in the view the car is loaded with 22 cu. yds. of gravel. The capacity of the car is 60,000 lbs. and it is equipped with air brakes. These cars are hoppered at the sides and ends, the hopper extending between and slightly below the inner axles of the two car trucks. The hopper has a door at the bottom 17 ft. in length, which is opened and controlled by chains winding upon a shaft. There is a lever and ratchet attached to the shaft at the end of the car, outside of the hopper, by means of which the door in the bottom of the hopper can be opened any desired width, so that the amount of ballast discharged is under control, being regulated by the amount by which the door is opened and the speed of the car. In unloading ballast from a train of these cars only one car is opened at a time and a ridge of ballast is deposited between the rails. If it is desired to unload ballast outside the rails a distributing car or spreader is coupled on at the rear of the train. This car consists of an ordinary flat car carrying a plow underneath, as shown in the lower view of the figure. This plow can be adjusted to any desired hight, but in service it is lowered by the screw and handle until it scrapes the rails. It plows all the ballast down to a level with the top of rail and flanges the track, leaving the excess material outside the rails, upon the ends of the ties. The quantity of ballast delivered is limited, necessarily, by an amount sufficient to pour over or cover the rails. Where the lift is not high, however, enough ballast may be plowed out across the rails to tamp the ends of the ties without unloading any outside the track from cars of other type. As used on the Union Pacific R. R. the wings of the plow were extended to spread enough gravel to make a 6-in. lift by putting all gravel unloaded under the ties. After this first raising enough material is plowed off to finish a 9-in. lift, fill in between the ties and trim out to the standard cross section.

This ballast car is used on a large number of roads. When not in use as a ballast car it can be put to service as a coal car. The Grand Rapids & Indiana Ry. has these cars built with a capacity of 100,000 lbs.; and when not in service in handling ballast they are used for transporting coal or ore. The Illinois Central R. R. also has combination cars of the Rodger type. In the summer the cars are used for hauling ballast and in the winter they are fitted with removable extension sides and ends and used in the coal traffic. The cars are 40 ft. long over end sills, 9½ ft. wide, outside, with a hopper 30½ ft. long on top and 24½ ft. long on bottom. The capacity of the car level full of ballast is 22 cu. yds. and 28 to 30 cu. yds. when heaped. The coal capacity is 40 to 42 tons. When used for carrying ballast the top part of the coal box, which is an extension of the hopper of 30 cu. yds. additional capacity, is removed. The weight of the car is 36,900 lbs. and the nominal weight capacity is 80,000 lbs.

The Rodger ballast car of improved design is convertible into a flat-bottomed gondola car. The car of improved design is similar to the old car, but having the addition of removable sloping ends and foldable longitudinal sections attached to the intermediate sills, which may be swung over to form a tight flat-bottom gondola car, overcoming the objection to the old-style Rodger ballast car, namely, that it was not available for ordinary freight service, although extensively used for carrying coal. The convertible car contains every feature of the old Rodger ballast car, having the same slope at the sides and a larger capacity, at the same time being convertible at the end of the ballasting season into a gondola car. A still later design is convertible into either a flat car or a flat-bottom gondola car.

Ordinary hopper-bottom gondola coal cars are frequently used for distributing ballast between the rails by skidding a square stick of timber ahead of the front wheel of the rear truck of each car dumped, to level down the ballast and spread it out across the rails. On the Lehigh Valley R. R. 160 "quarter" coal-car loads of slag measuring 1000 cu. yds. have been unloaded in this manner by a crew of 18 men in $\frac{1}{2}$ day, the men being employed, for the most part, in pushing the slag down into the hoppers with bars. After raising the track to grade and tamping it with slag that material was leveled down even with the bottoms of the ties, and cinder ballast for filling was dumped in the same manner.

Another very well known car for hauling either ballast or filling material is the Goodwin car, in use on a large number of roads. This car is made to dump either at the side or from the center or from both

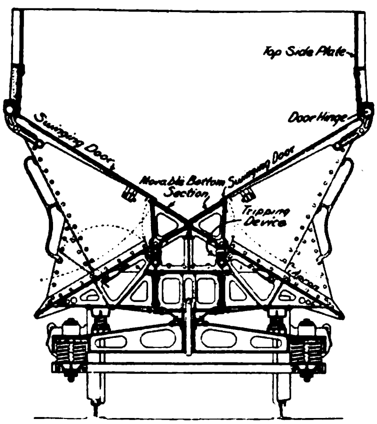


Fig. 44.—Goodwin Dump Car.

Table VII.—For Finding Degree of Curve.

Deg. of Curve	Radius of Center Line.	No. of 30 ft. Rails in Arc "ABC"	Length of Arc "ABC" in feet.	Length of Chord "AC" in feet.	Central Angle.
½°	11459	22—	656.8	656.7	3°17'
1°	5730	15⅓—	463.5	463.4	4°35'
2°	2865	11—	328.6	328.4	6°34'
3°	1910	9—	268.5	268.2	8°03'
4°	1433	8—	233.6	233.3	9°17'
5°	1146	7—	216.1	207.8	10°23'
6°	955.4	6⅓	190.0	189.7	11°22'
7°	819.0	5 5-6+	176.0	175.6	12°17'
8°	716.8	5½—	164.7	164.3	13°07'
9°	637.8	5 1-6+	155.3	154.9	13°55'
10°	573.7	4 9-10+	147.4	147.0	14°40'
11°	521.7	4⅝+	140.6	140.2	15°22'
12°	478.3	4⅓—	134.7	134.2	16°03'
13°	441.7	4 3-10+	129.5	129.0	16°42'
14°	410.3	4 1-6—	124.8	124.3	17°20'
15°	383.1	4+	120.6	120.1	17°56'
16°	359.3	3 9-10—	116.8	116.3	18°31'
17°	338.3	3 8-10—	113.4	112.9	19°04'
18°	319.6	3 7-10—	110.3	109.7	19°37'
19°	302.9	3 6-10—	107.4	106.8	20°09'
20°	287.9	3 5-10—	104.7	104.1	20°40'

outlets at the same time. The car as now built is constructed entirely of steel and iron. As shown in the cross-sectional view, Fig. 44, the body of the car is built upon two plate-girder sills 21 ins. apart. These girders are 18 ins. deep at the middle and $9\frac{1}{2}$ ins. deep at the ends. The space between the sills is left clear for dumping the load between the rails, and from each sill there is an apron or floor inclining downwards. The two ends of the car are connected by top side plates 18 ins. deep and the car is divided at the middle by a transverse bulkhead, so that either of the two compartments can be dumped independently of the other. To the top side plate on each side of the car, in each compartment, there is hinged a swinging door which, when the car is loaded, rests upon the projection of a movable section in the bottom of the hopper. This bottom is composed of two narrow movable sections hinged to a longitudinal shaft. Each bottom section is held in position by a tripping device, by means of which the said movable section on either side of the car may be released, when it swings downward, inclining toward the apron, thus releasing the swinging door and permitting the discharge of the load. The apron is hinged along its middle line (longitudinally), so that the upper portion can be swung upward, as shown by the broken lines at the left side of the figure. When the upper section of the apron is set in this position and the swinging door released, the latter strikes against, and is held by, a spring on the raised portion of the apron and the contents of the car are discharged between the sills and inside the rails of the track. The dumping devices are arranged to be operated either by hand or by compressed air. A view of the car with the swinging doors open is shown as Fig. 45. Hand dumping is accomplished by the wheel at the end. When equipped for pneumatic dumping an air cylinder is attached to the end of the car, on the outside, beside the hand wheel. This car can be made to discharge half of its load on one side and half on the other; or half in the center and half on the outside; all on one side or all in the center, as is desired. The car is 35 ft. 11 ins. long over the end sills, 8 ft. 10 ins. wide over all, and the extreme hight above top of rail is 8 ft. 6 ins. The carrying capacity is 80,000 to 125,000 lbs. or in volume, with the load heaped, it amounts to about 29 cu. yds. As shown in Fig. 45, the ends of the car are of wood construction, but in later designs the ends are constructed entirely of steel. These cars are constructed with a view to turning them to service for carrying coal, ore, grain and other bulky freight. For grain service the car is provided with an adjustable steel top for protecting the grain from the weather, and for carrying coke there is a top crate which enlarges the capacity to 37 cu. yds.

There are other ballast cars of well known patterns, used either in supplying ballast for new track or for renewing the ballast on old track, described in the chapter on "Work Trains" (§ 148, Chap. X). In ballasting, or, rather, surfacing, track with dirt but little or no hauling is

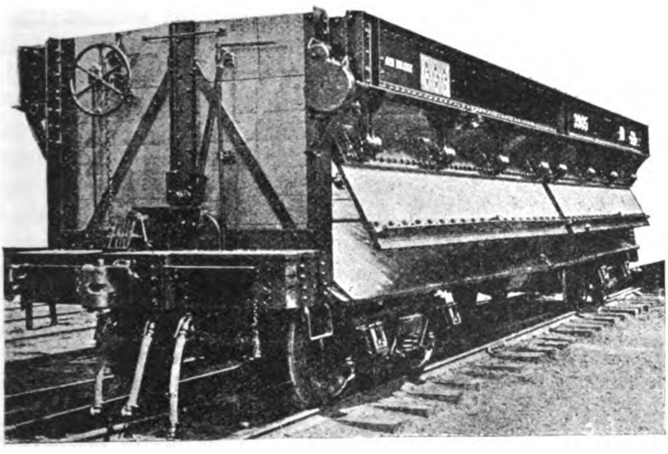


Fig. 45.—Goodwin Dump Car with Swinging Doors Open.

usually done, as in such material the track is not usually raised very high above the sub-grade, and enough material can in most places be had by casting up from the side or from the ditch; but holes should not be dug out of embankments for this purpose nor should irregular enlargements be made in the ditches, where they will hold water in puddles.

37. Lining.—After the track has been tamped, and before it is filled in, it should be lined. It can be easier thrown before it is filled in than afterward, as there is then not so much material to hold the ties, and besides, the rail is more free to align itself farther from the point at which it is thrown, thereby lessening its tendency to kink and require throwing at more frequent intervals. The foregoing applies to track in most kinds of ballast, but in stone or slag ballast the track should be lined before it is tamped the last time, because when track is thrown on freshly placed ballast of these kinds the pieces of stone will roll and raise it out of surface. As a guide in throwing the track to the center stakes a tack is driven in the middle of the gage, or it is notched at that point. The gage is then placed across the rails at each center stake and the track is thrown to bring the mark on the gage vertically over the tack in the stake. It is well to place pebbles or other small objects on the rail at such points to designate the place. The crew then goes back and throws the joints, centers, and quarters if need be, to line with the rail at these designated places. Six men will usually be a large enough force to handle it easily, and in some cases four will be sufficient. They should all throw together, at the word, with a rather steady pull or heave, not trying to jerk too quickly. At some places where there is a short kink the rail must be held at one place while throwing it at another, so as to avoid throwing out of line the portion which is so held.

One often sees in railroad periodicals inquiries after the best method of lining track. All there is of it is simply the use of a fair "mechanical eye" to put the rail in line over stretches of 50 or 100 ft., although, for that matter, center stakes on tangents need not be nearer than 200 ft. apart. It is the practice with some young engineers to line tangents by sighting along the rail with a transit. Possibly such work may convey the impression of accuracy, but it cuts no figure in track work. When the unaided eye cannot detect any portion of a rail out of line it is certainly not going to affect the running of trains; moreover, in curves, where good alignment is most needed, the transit can be of no use in this way, and the eye must be, and has always been, depended upon.

38. Filling in and Dressing.—After the track is lined it is filled in and dressed off. The manner of filling in depends a good deal on the quality of the ballast. Track in broken stone, ordinary gravel, cinder and like kinds of ballast should be filled in full, even with the tops of the ties inside the rails, but not over the tops. For a distance of 6 ins. inside the rails, however, and from there on out to the end of the tie, the ballast should be just enough lower to nicely clear the rail base. If the ballast be even with the rail base, sand or dirt will be sucked in between it and the tie face, as the rail springs up and down under trains, and in winter the flange of the rail between the ties will lie in a frozen rut which will be a hindrance to shimming and other kinds of work which must sometimes be done. The expansion or heaving of the ballast is also liable to lift the rails from the ties and start the spikes. Beyond the ends of the ties the ballast should be shouldered out full depth a distance of at least 8 ins., and better if 10 or 12 ins. Ballast banked against the ends of the ties helps very much to hold the track in line. It also keeps the ground from freezing that much deeper in winter, and in case of derailment gives some aid to the wheels and protection to the ties. The portion just outside the ends of the ties is usually called the ballast shoulder. From the top of the shoulder the ballast may be sloped off gradually toward the ditch or edge of fill; broken stone ballast is usually sloped off more abruptly—something like 1 to 1, say. Figures 3 and 4 illustrate the manner of filling for different kinds of ballast. If too much ballast has been left during construction it may remain to be used in repairs later on, but no material should remain piled in a ditch or in a cut.

In all kinds of loose ballast through which water soaks away readily little attention need be given to dressing the material with a view to draining the water off the top; but in dirt ballast, and, to some extent, in sand ballast also, the conditions are different. In those cases the ballast must be so dressed that it will run all water possible off the top and keep it from getting underneath the ties. The only thing which makes dirt a practicable ballast is good surface drainage. Dirt and sand ballast should be rounded up 2 or 3 ins. higher than the tops of the ties in the middle of the track, covering the ties over a strip about 3 ft. wide, and then sloped down to the bottoms of the ties at their ends, passing 1 or 1½ ins. under the rail base. The standards of some roads require that between the rails the ties shall be covered as far as a line 3 ins. from the rail base, from which point the ballast shall be sloped down to the bottoms of the ties at their ends, "care being taken to leave an opening under the rail for drainage." Outside the ends of the ties the surface should slope away gently out over the shoulder. Engraving *G*, Fig. 4, shows the arrangement. On quite a number of roads, one of which is the Illinois Central (Fig. 5), it is the practice to fill in and dress off cementing gravel ballast in this manner; that is, to heap it up in the middle of the track and slope it down to the bottoms of the ties at their ends. Cementing gravel does not pass water freely, and it is so difficult to work that much labor is saved by leaving the ends of the ties uncovered, so that they may be readily opened out for tamping.

There are several objectionable effects from the banking of ballast inside the rails, two or three of which it may be well enough to remark upon. Where ballast is dressed in this manner there is always a tendency to center-binding of the track. In the first instance, as elsewhere stated, the ballast or earth under the exposed ends of the ties is not as well retained as it is under the middle of the track where there is a full depth of filling. When the ground is thawing the frost leaves from under the ends of the ties before it does the middle of the track. The effect of this condition is inequality of support and a slight rocking of the track which causes it to settle out of surface. Nevertheless, in the qualities of ballast under consideration, the advantages obtained by covering the ties in the middle of the track outweigh the disadvantages. Aside from the superior drainage effected, the heap of ballast in the middle of the track assists materially in holding the track in alignment. When heaping the filling in curved track it is usual to crown it on the outer side of the center line, which brings the highest point of the filling nearer the outer than the inner rail; otherwise it might not be possible on track highly elevated to make the filling slope both ways.

When dressing off filling for the first time, except in dirt ballast, it is not worth the while to spend any time at work intended merely to make a neat appearance, because the track will soon settle and have to be raised. At the first dressing merely "cuff" it over roughly with the shovel, but after the track has been put in good surface the second time, it may be dressed off more carefully. In dressing off stone ballast it puts a "finishing touch" on appearances to lay a margin of stones to line on the shoulder, parallel with the rails, but opinions regarding the utility of such work are likely to be influenced by personal tastes.

On double track, where the ballast is retentive of water, a ditch becomes necessary between the tracks. It should be provided at intervals with lateral drains or outlets under one of the tracks. Where the ballast is of good quality, however, such as gravel, broken stone, or of any porous material, the space between the tracks is usually filled in full and a ditch is not needed. On this question, however, opinions seem to differ, for on a number of double-track roads where gravel ballast is used the filling between the tracks is depressed to drain toward a center ditch. On the gravel-ballasted road of the New York Central & Hudson River R. R. the filling between parallel tracks on the same roadbed is depressed 7 to 9 ins. and cross drains are placed at intervals of 400 to 500 ft. apart, to drain the depressions. These drains are 6x6-inch boxes made of 2-in.

plank treated with three coats of Woodiline or Fernoline, or creosoted with dead oil of tar. The cross drains are run each way from the center line of the roadbed, deep enough to permit tamping, and at an inclination of at least 1 in 12. Use has been made of center drains 8 ins. lower than the bottoms of the ties, with tile drains leading under the track at intervals of 500 ft., but the results of this style of dressing track have been reported unfavorably. In the first place, the ditch was too low and it was found that the gravel from each side was shaken into the ditch, obstructing the same; and lumps of coal, leaves and other rubbish had obstructed the tile drains. A scheme of tile-draining the roadbed to carry off the water which soaks through the ballast is elsewhere referred to (§ 3, Chap. I).

39. Quantity of Ballast Required.—To fill in track properly with ballast, between the ties and for a foot outside the ends, even with the tops of the ties, requires about 16 cu. yds. of material per 100 ft. of single track. For every inch below the bottoms of the ties, about 4 cu. yds. of ballast is required per 100 ft. of track. For double track, 13 ft. centers, filled full between the tracks evenly with the tops of the ties, about $2^1/_5$ times the above amount will be required for filling down as far as the bottoms of the ties—that is, about 35 cu. yds. per 100 ft.; for ballast below this point, double the figure, or 8 cu. yds. per 100 ft., per inch in depth.

How Track is Ballasted in Baluchistan.

In the above scene native laborers are ballasting track with broken stone, on the Muskaf-Boulan Ry., in Baluchistan. The ties are of pressed steel, weighing 160 lbs. each. These natives have but little strength in their arms, and it takes two of them to work a shovel—one pushing on the handle and another pulling on a rope tied to the tool near the blade.

CHAPTER V.

CURVES.

40.—Track can be made to change direction either by an angle or by a curve. When direction is changed by an angle it changes suddenly, as it were, and at a point, or all at one place; when by a curve, it changes gradually at every point along the curve. The first method is occasionally resorted to for main track where the change in the direction is small, but is most frequently employed at split switches, the angle commonly used being about 1 deg. 40 min. In changing the direction of track by a curve it is laid to form part of the circumference of a circle, or parts of the circumferences of two or more circles. The first mentioned arrangement is called a "simple" curve; the second, a "compound curve" when the different parts turn in the same direction, and a "reverse curve" when they turn in opposite directions. The use of the circle applies to the main portion of practically all railroad curves, but curves more complicated than the circular one, for the purpose of an easement at the ends of the circular portion, are largely employed. Such curves change direction by a gradually varying rate instead of a uniform rate, and are known by various names, such as "spirals," "transition" curves, "easement" curves, "tapering" curves, etc.—all meaning about the same thing. In laying out curves of any kind it is well to avoid, as far as possible, locating them on bridges; and where too much will not be sacrificed the grade of track should not be changed in a curve.

41. Simple Curves.—The circumference of a circle is the simplest curve because it is the easiest drawn or laid out, and because its form is everywhere the same. Any straight line which touches the circumference of a circle without cutting it, however far the straight line may be produced, is called a *tangent*. At the point of contact the tangent has the same direction as the curve, and it is perpendicular to the radius drawn to that point. Likewise a straight line touching any curved line without intersecting or cutting across it, however far produced, is called a tangent, and two curves are tangent to each other when they are both tangent to the same straight line at the point of contact. In railroading every piece of straight track is called a tangent, because it is supposed to meet tangent to a piece of curved track somewhere.

Circular railway curves are referred to by the length of radius or by the degree of curvature. By the *degree of curve* is meant the degree of the angle included between two lines drawn from the center of the circle to any two points on the curve 100 ft. apart, measured in a straight line; or, more concisely stated, perhaps, the degree of a curve is the angle which a chord of 100 ft. subtends at the center. For curves of radius less than 50 ft., such as are found on street car tracks, this definition obviously fails, for in that case there is no chord of 100 ft., but very sharp curves are usually designated by the radius. There is another definition that makes no reference to the center or radius, which describes the degree of curve as the change in the direction of the curve between two points 100 ft. apart. In foreign countries the curvature is expressed by the length of radius. In English practice the chord length in railway curves is one chain, or 66 ft., and the curvature is referred to by the length of the radius in chains. Where the metric system is employed the chord length is 20 meters or 65.62 ft. In speaking of curvature in track reference is always made to the center line of the track. Neither rail has exactly the same degree of curvature as the center line, or as the other rail—the outer rail is of longer radius and less degree than the center, and the inner rail is of shorter radius and greater degree than the center. On double track, the two tracks being the same distance apart everywhere, or parallel, both tracks cannot have exactly the same degree of curvature. For instance, if the outer track be a 10-deg. curve and the tracks are 14 ft. between centers, the inside track will have a curvature of 10 deg. 15 min., or 10¼ deg.

To make these matters clearer to persons not familiar with the mathematics of railroad curves, let us refer to Fig. 46, not drawn to scale. From a point *c* draw two straight lines making with each other

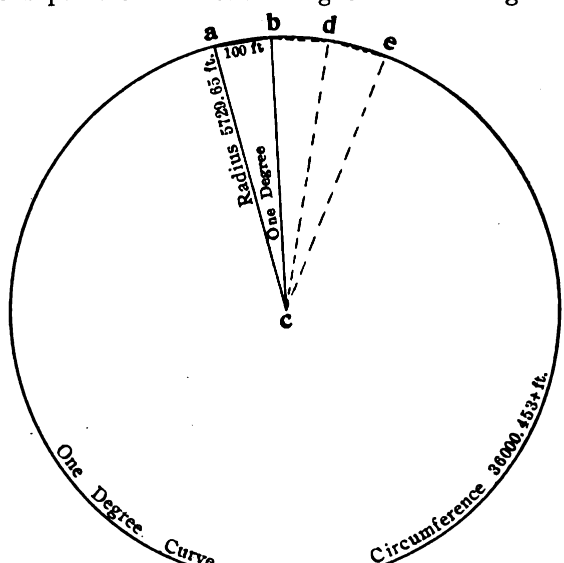


Fig. 46.—One-Degree Curve.

an angle of one degree, and let them diverge until they are 100 ft. apart at points *a* and *b*, equally distant from *c*; this occurs when *a c* and *b c* each becomes 5729.65 ft. in length. We then have the isosceles triangle *a b c*. Now it is plain that around the point *c* there can be drawn 360 such triangles, thus filling up the whole angular space about it. We shall then have a 360-sided regular polygon, the total length of whose sides will be 360×100 ft.=36,000 ft. If now a circle be circumscribed about this polygon it will have *c* for a center and 5729.65 ft. for a radius; and any portion of its circumference will constitute what in railway engineering is called a 1-degree curve. The sides of the polygon so nearly coincide with the circumference of this circle that the difference between the total length of all sides of the polygon and the circumference is only a very small amount, comparatively (really 0.453+ft.). The radius of a 1-deg. curve is then 5730 ft., very nearly; and, nearly enough for practical purposes, the radius of any curve used on steam railroads is 5730 ft. divided by the degree of the curve. Table VI. gives the radii of curves up to 50 deg. There is nothing concerning the ordinary use of simple curves that is complicated, and any roadmaster or section foreman who has been so fortunate as to have gained a knowledge of the geometry of the circle and a smattering of trigonometry can easily acquaint himself with the necessary knowledge concerning them, and should by all means do so.

42. Some Ways of Laying Out Curves.—No man who is not able to master an ordinary book on field engineering should, as a rule, be given charge of locating and laying out curves; yet there are times when exigencies arise such that a man competent to do a little calculating may not have a transit at hand, but is able to lay out curves quite accurately without the transit if he has at hand a field book or the necessary tables. For this reason, then, two methods of laying out curves by the use of a tape line or chain, as the only instrument, will be given. These methods are useful in rerunning or relocating old curves or in laying out short stretches of new track or side-track, when a surveyor with transit cannot be had. There are many railways of short length in this country which cannot afford to retain a regularly employed surveying party in idleness a large part of the time, and so occasionally these "unprofessional" methods come handy. I have seen many examples of very creditable work done in this manner, where stretches of track over considerable distances were laid out anew or relocated, and which checked up closely enough with transit work afterwards.

Method of Middle Ordinates.—The problem most frequently arising is that of laying out a curve between two tangents meeting at a given angle. Let, in Fig. 47, *A B* and *C D* be the two tangents. The angle *B C D* is the intersection or Δ (delta) angle, as it is generally called. Find Δ by laying off with tape line the right triangle *B C E,* and compute *tangent B C E* or *tang.* $\Delta = B\ E \div C\ E$. The angle corresponding to this tangent value can be picked from a table of tangents (Table V. See in-

Table VI.—Tangent Offsets, Chord Deflections and Middle Ordinates for 100-ft. Chords.

Degree of Curve.		Radius.	Tangent Offset.	Chord Deflection.	Middle Ordinates.	Degree of Curve.		Radius.	Tangent Offset.	Chord Deflection.	Middle Ordinates.
Deg.	Min	Feet.	Feet.	Feet.	Feet.	Deg.	Min.	Feet.	Feet.	Feet.	Feet.
0	15	22918	0.218	0.436	0.055						
0	30	11459	0.436	0.872	0.109						
0	45	7639.5	0.654	1.308	0.164						
1		5729.6	0.873	1 746	0.218	13		441.7	11.32	22.64	2.839
1	15	4583.7	1.091	2.182	0.273	13	15	433.4	11.54	23.08	2.894
1	30	3819.8	1.309	2.618	0.327	13	30	425.4	11.75	23.50	2.949
1	45	3274.2	1 527	3.054	0.382	13	45	417.7	11.97	23.94	3.003
2		2864.9	1 745	3.490	0.436	14		410.3	12.19	24.38	3.058
2	15	2546 6	1.963	3.926	0.491	14	15	403.1	12.40	24.80	3.113
2	30	2292.0	2.181	4.362	0.545	14	30	396.2	12.62	25.24	3.168
2	45	2083.7	2.400	4.800	0.600	14	45	389.5	12.84	25.68	3.222
3		1910.1	2.618	5.236	0.654	15		383.1	13 05	26.10	3.277
3	15	1763.2	2.836	5.672	0.709	15	30	370.8	13.48	26.96	3.387
3	30	1637.3	3.054	6.108	0.763	16		359.3	13.92	27.84	3.496
3	45	1528.2	3.272	6.544	0.818	16	30	348.4	14.35	28.70	3.606
4		1432.7	3.490	6.980	0.872	17		338.3	14.78	29.56	3.716
4	15	1348.4	3.708	7.416	0.927	17	30	328.7	15.21	30.42	3.825
4	30	1273.6	3.926	7.852	0.982	18		319.6	15.64	31.28	3.935
4	45	1206.6	4.141	8.288	1.036	18	30	311.1	16.07	32.14	4.045
5		1146 3	4.362	8.724	1.091	19		302.9	16.50	33.00	4.155
5	15	1091.7	4.580	9.160	1 146	19	30	295.2	16.93	33.86	4.265
5	30	1042.1	4 798	9.596	1.200	20		287.9	17.36	34.72	4.374
5	45	996.9	5.016	10.03	1.255	21		274.4	18.22	36.44	4.594
6		955.4	5.234	10 47	1 309	22		262.0	19.08	38.16	4.814
6	15	917.2	5.451	10.90	1.364	23		250.8	19.94	39.88	5.035
6	30	881.9	5.669	11.34	1.418	24		240.5	20.79	41.58	5.255
6	45	849.3	5.887	11.76	1.473	25		231 0	21.64	43.28	5.476
7		819.0	6.105	12 21	1.528	26		222.3	22.49	44.98	5.697
7	15	790.8	6 323	12.65	1 582	27		214.2	23.34	46.68	5.918
7	30	764.5	6.540	13 08	1.637	28		206.7	24.19	48.38	6.139
7	45	739.9	6 758	13.52	1.691	29		199.7	25.04	50 08	6.360
8		716.8	6 976	13.95	1.746	30		193.2	25.88	51.76	6.583
8	15	696.1	7.193	14.39	1.801	31		187.1	26.72	53.44	6 805
8	30	674.7	7.411	14.82	1.855	32		181.1	27.56	55.12	7.027
8	45	655.4	7.628	15 26	1.910	33		176.0	28.40	56.80	7.250
9		637.3	7.846	15.69	1.965	34		171.0	29.24	58.48	7.473
9	15	620.1	8.063	16 13	2.019	35		166.3	30 07	60.14	7.696
9	30	603 8	8.281	16.56	2 074	36		161.8	30.90	61.80	7.919
9	45	588.4	8.498	17.00	2.128	37		157.6	31.73	63.46	8.143
10		573.7	8.716	17.43	2.183	38		153.6	32.56	65.12	8.367
10	15	559.7	8.932	17.86	2.237	39		119.8	33 38	66.76	8.592
10	30	546.4	9.150	18.30	2.293	40		146.2	34.20	68.40	8 816
10	45	533.7	9.367	18.73	2.347	42		139.5	35.84	71.68	9.267
11		521.7	9.585	19.17	2.402	44		133.5	37.46	74.92	9.719
11	15	510 1	9.801	19.60	2.457	46		128.0	39.07	78.14	10 17
11	30	499.1	10 02	20.04	2.511	48		122.9	40.67	81.31	10.63
11	45	488.5	10 23	20.46	2.566	50		118.3	42.26	84.52	11.08
12		478.3	10.45	20.90	2.620						
12	15	468.6	10.67	21.34	2.675						
12	30	459.3	10.89	21.78	2 730						
12	45	450 3	11.10	22.20	2.784						

dex). The length of tangent for the curve is $T = R \times tang.\ \frac{1}{2}\Delta$, where R is the radius of the proposed curve. Lay off the tangent length each way from C, to F and to G. Let an example be taken. In order to draw $B\ E$ perpendicular to $C\ D$, take any point B, on line AB, and from B as a center and with $B\ C$ as a radius cut the line $C\ D$ at N; E will then lie half way between N and C. Now suppose that $B\ E$ measures 7.5 ft. and $C\ E$ 12 ft. Then $tang.\ \Delta = 7.5 \div 12 = .625$, which value corresponds to the tangent of 32 deg. within a half minute; Δ then $=$ 32 deg. Suppose it is desired to lay off an 8-deg. 30-min. curve (8° 30′ being the conventional way of expressing it). From Table VI we find the radius of such a curve to be 674.7 ft. The tangent length for the curve will then be $T = 674.7 \times tang.\ 16° = 674.7 \times .28675 = 193.5$ ft. $F\ C$ and $C\ G$ then each equal 193.5 ft. Having now the starting point and ending point of the curve, it may be laid off by the method of middle ordinates or by the method of deflections from tangent and chords produced.

The middle ordinate of a chord is the perpendicular distance from the middle of the chord to the curve; it may be found very approximately

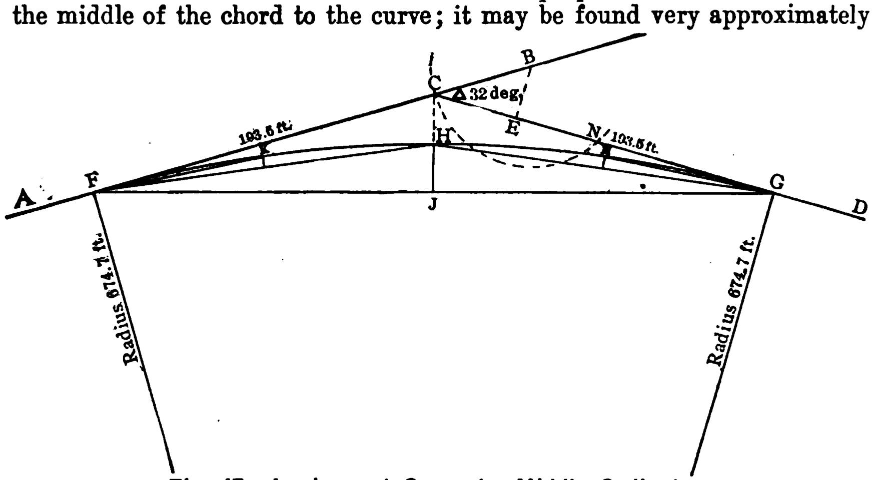


Fig. 47.—Laying out Curve by Middle Ordinates.

by dividing the square of the chord length by 8 times the radius of the curve. For a 100-ft. chord the middle ordinate is equal to the radius multiplied by the versed sine of half the degree of the curve. In Fig. 47, JH, the middle ordinate of the long chord FG, is $R \times vers.\ \frac{1}{2}\Delta$, and, as a check, the distance $C\ H = R \times Ex.\ Sec.\ \frac{1}{2}\Delta$. The middle ordinate of the chord $F\ H = R \times vers.\ \frac{1}{4}\Delta$; of chord $F\ K$, $R \times vers.\ \frac{1}{8}\Delta$, and so on as far as it is desirable to go. For the long chord $F\ G$ a wire may be stretched. The length of curve in 100-ft. stations and fractions therefore, is Δ divided by the degree of the curve or, in this case, it is $32 \div 8\frac{1}{2} = 3.76$ stations$=$376 ft. From Table V and the foregoing formulas, then, we get:

$J\ H = R \times vers.\ 16° = 674.7 \times .03874 = 26.2$ ft.

$C\ H = R \times Ex.\ sec.\ 16° = 674.7 \times .04030 = 27.2$ ft.

Middle ordinate of $F\ H = R \times vers.\ 8° = 674.7 \times .00973 = 6.56$ ft.

Middle ordinate of $F\ K = R \times vers.\ 4° = 674.7 \times .00244 = 1.65$ ft.

The middle ordinate of $K\ H$ is the same as that of $F\ K$. The middle ordinates for chords between H and G are the same as for corresponding ones between F and H. Without appreciable error the middle ordinate of $F\ H$ may be taken at $\frac{1}{4}\ JH$, and the middle ordinate of $F\ K$ at $\frac{1}{4}$ that of $F\ H$, or $^1/_{16}\ J\ H$. This is the most accurate method of laying out curves by measurements alone, because no sighting is required. The point J may, however, be located by measuring and sighting, without stretching a string or wire.

Method of Tangent Offsets and Chord Deflections.—Where it is not feasible to stetch a wire, the distance being too long, or the ground inaccessible, or where the two tangents are not located, or where the intersection point is inaccessible, the curve may still be laid off quite readily by tangent offsets and chord deflections. Starting on the tangent (Fig. 48), set a stake at B, 100 ft. from A, the point of curve. An offset to C, equal to the tangent offset, will give the first station on the curve. Then by producing the chords 100 ft. beyond the last point of curve found each time, and setting off the chord deflections $F\ D$, $G\ E$ etc., successive points around the curve can be found. To get on tangent again, as at E, a full station, produce the chord $D\ E$ one station beyond E and lay off the tangent offset $H\ I$, which is always $\frac{1}{2}$ the chord deflection. If the last chord be less than 100 ft., the tangent offset for it may be found by multiplying the tangent offset for 100 ft. by the square of the sub-chord and dividing by 10,000.

The chord deflection for a 100-ft. chord may be found by dividing 10,000 by the radius of the curve. It is not necessary, however, to use a chord of 100 ft. The chord deflection for a chord of any length may be found by dividing the square of the chord by the radius of the curve. It should be noted that, to be exact, the tangent offset $B\ C$ is not laid

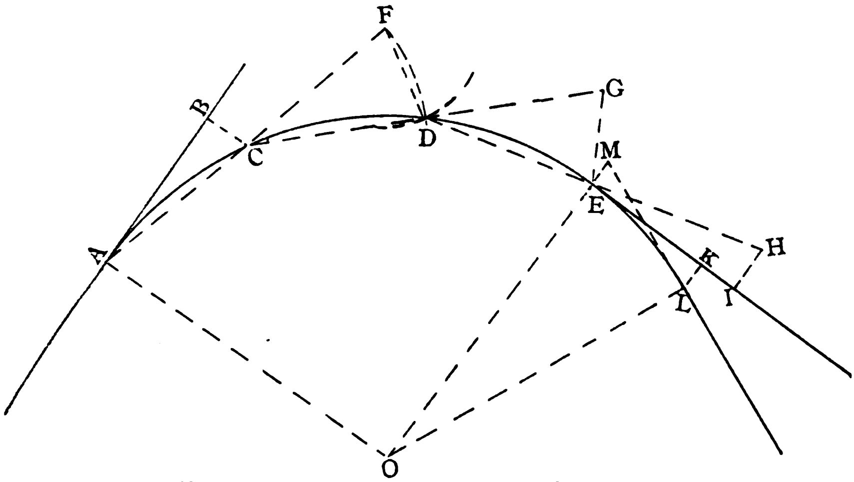


Fig. 48.—Tangent Offset and Chord Deflection Method

off from B, but perpendicular to $A\ B$ in such manner as to meet the line $A\ C$ 100 ft. (or whatever chord length) out from A. No noticeable error will arise, however, in making $A\ B$ equal in length to $A\ C$, for curves of small degree. It must also be noted that $F\ D$ is not perpendicular to $C\ F$, but is so measured that $C\ F$ and $C\ D$ are equal; that is, having measured off and set the stake at F, swing the tape with a radius $C\ D = C\ F$ and set a stake at D, the intersection of the two radii $F\ D$ and $C\ D$.

In the example at hand, we find, in Table VI, the tangent offset $B\ C$ corresponding to 8° 30′ to be 7.41 ft., and the chord deflections $F\ D$ and $G\ E$ to be 14.82 ft. As the curve has been found to be 376 ft. long, the last chord is a sub-chord of 76 ft., for which the tangent offset required will be $(76^2 \div 10{,}000) \times 7.41 = 4.28$. In this case, then, we would make $E\ I$ tangent to the curve at E just as has been done in the figure for a full station. Then, measuring off $E\ K$ equal to 76 ft., make the offset $K\ L$ equal to 4.28 ft. L is then the end of the curve, and the direction of the tangent may be found by laying off $E\ M$ from E equal to K L, or 4.28 ft. A line drawn through M and L gives the direction of the tangent. Points on the curve midway between A and C, C and D, etc. may be set by the foregoing method of middle ordinates. Middle ordinates for 100-ft. chords are given in Table VI.

In order to lay off a curve so as to pass through a given point, which is a problem often arising, draw a tangent through that point to intersect the tangent on which the starting point is situated and connect the two tangents with a curve. For example, suppose it is required (Fig. 49) to reach the point B by a curve starting from A on the line $A\ E$. Connect $A\ B$ and find C, its middle point, by sighting or by stretching a wire, and measuring. Draw through B a line to meet $A\ E$ in D, so that $B\ D = A\ D$. The point D may be found by drawing from C a line perpendicular to $A\ B$ to intersect AE; or it may be found quite readily

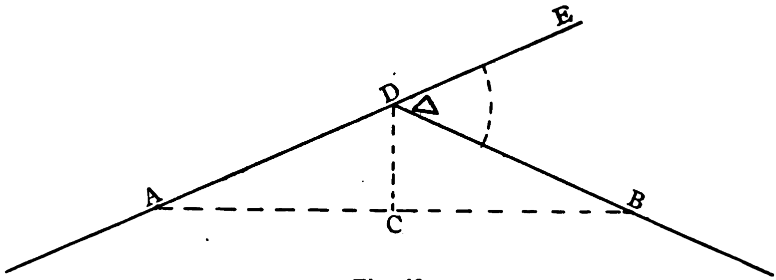


Fig. 49.

by estimating the length $B\ D$ and "cutting and trying" once or twice. Having the two tangent distances and the intersection or Δ angle $E\ D\ B$, the radius for the proper curve to connect A and B will be

$$R, = \frac{\textit{tang. dist.}}{\textit{tang.}\ \frac{1}{2}\Delta} = \frac{AD}{\textit{tang.}\ \frac{1}{2}\Delta}$$

Having the radius we can now lay off the curve by the method of middle ordinates or by tangent offsets and chord deflections, as best suits the case.

43. To Find the Degree of Curve.—Where there are not marked monuments or records of some kind at the curve it often becomes necessary to measure the degree of curve. The middle ordinate of a 62-ft. (more exactly 61.8 ft.) chord, measured in inches, gives the number of degrees curvature. That is, stretch tightly along the gage side of the outer rail a string or chord 62 ft. long. The number of inches from the middle of the string to the rail is the degree of the curve. If, however, the curve be out of line at the place where the string is stretched, there is liable to be quite a large discrepancy, if so short a chord be taken. It is always best, therefore, when using such a short chord to get a mean of several measurements taken at different places in the curve; but if a long chord be used, the fact that a rail or two is out of line does not so much affect the result. The middle ordinate for a chord of other length is approximately the length of the chord squared, divided by 8 times the radius of the curve. If the values in this computation are expressed in feet the result—that is, the middle ordinate—will be in feet.

There is always a middle ordinate of 4 ft. 8½ ins. available without making a measurement. That is the gage of the track; and by sighting across the rails, the length of arc for the chord of which the gage of the track is the middle ordinate may be known by counting the rails. By the use of a short table it is a very convenient way of getting at the degree of curve, either with the transit or by the eye unaided. Not so much as a tape line, string, or rule is necessary, for ordinary degrees of curvature. By sighting over a joint on the outer rail of the curve, on a line of sight which just touches the gage side of the inner rail of the curve, and counting the number of rails from the point where this line of sight intersects the outer rail beyond, back to the joint sighted across, gives a length of arc which corresponds to a certain degree of curve. On curves of over 10 deg., one should sight quite carefully. Figure 50 will explain the method more clearly, perhaps. Sight across some joint, as at C, on a line of sight which just touches the gage side of the inner rail at D; this line of sight cuts the outer rail again at A. Count the number of rails from A

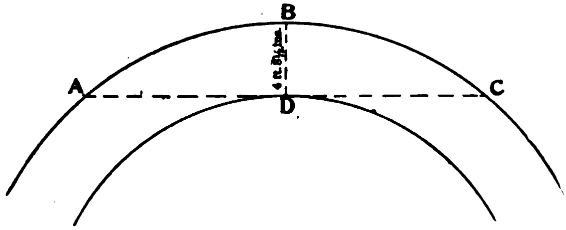


Fig. 50.—To Find Degree of Curve.

back to C or measure the distance; and opposite this distance in Table VII (shown with Fig. 44) pick out the degree of curve. This method and the table are credited to Mr. Wm. A. Pratt, formerly division engineer with the Baltimore & Ohio R. R.

44. The Action of Car Wheels on Curves.—On curved track car wheels meet with certain constraints and resistances to movement which cause them to take definite and peculiar positions with respect to the rails. An understanding of the characteristic behavior of wheels on curves assists very much to account for the various conditions imposed upon the track maintenance and also to devise methods of work and standard rules governing such conditions. The unequal wear of the rails, the spreading of the rails, the canting of the inner rail, the superelevation of the outer rail and the question of widening the gage, all stand in an important relation to the action of the wheels on the curves.

The immediate effect of joining two wheels solidly with an axle is that both wheels must turn together through equal angular distances. The consequence is that if both wheels have the same diameter they tend to run equal distances, and hence the tendency to run straight ahead. The additional force which it takes to haul cars around curves, above that required to haul them along tangents, is used up in three ways: (1) A force to all times keep the two wheels turning through equal angular distances, which force is transmitted from wheel to wheel through the axle and continually keeps one or both wheels slipping on the rail; (2) a force to keep constantly swinging the axle into its proper position radial to the curve, or nearly so, thus opposing the tendency for the wheels to run equal distances; and (3) a force to overcome the retarding tendency in the rotation of the wheel due to the friction of its flange against the rail. With a single pair of loose wheels the last force (3) is the only one adding to the resistance on curves above that on tangents; but with four loose wheels joined as in a truck, both (2) and (3) enter into the curve resistance fully as much as though the wheels were solidly attached to the axle. The resistance which curves offer to the movement of trains is of course widely recognized, it being customary, where curves occur on grades of considerable importance, to compensate for the increased resistance by easing the grade .02 to .05 per cent per degree of curvature. In average practice the rate is .03 to .04 per cent.

Consider the simple case of a single pair of car wheels and an axle, supposing them to be pushed around curved track in the same manner that one would push a lawn mower; and let Engraving *G*, Fig. 51, represent such a contrivance in diagram. A device built on this principle is actually used for the forward truck of two classes of locomotives. Let the axle in starting have a position (*A B*) radial to the curve. The direction of the handle by which the wheels are pushed is then, to start with, tangent to the center line of the curve at the axle. Now if the axle is to remain radial to the curve, it is plain that the two wheels cannot travel equal distances, because the outside rail in track of standard gage is the longer, between radial lines to the curve 100 ft. apart, by over an inch per degree of curve. The two wheels, then, if of equal diameters, cannot run equal distances for a single revolution and maintain the position of the axle radial to the curve; but unless the axle can in some way be swung, the farther they run, the farther will the axle depart from a

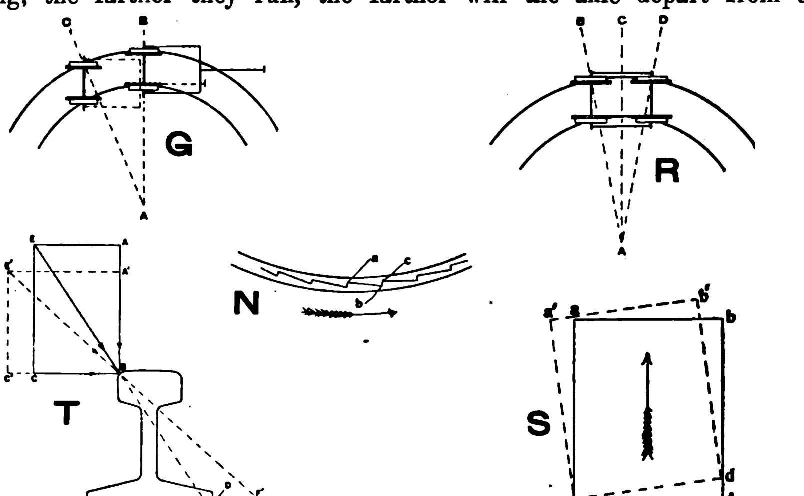


Fig. 51.

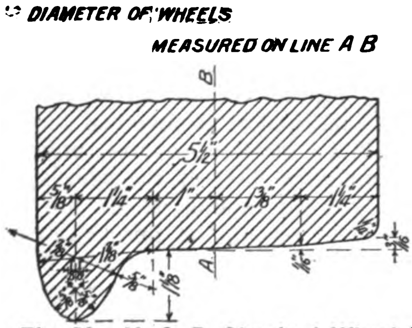
radial position, until it becomes so skewed to the rails that either the outside wheel will mount the rail or else the inside wheel will drop between the rails. It must be plainly seen that to keep a pair of wheels on the rails the axle cannot depart from a position radial to the curve by more than a limited amount; and it will subsequently be shown that the nearer to the radial position the axle is kept, the less will be the resistance which the curve will offer to the passage of the wheels.

It is apparent that if the inner wheel referred to in the figure was smaller in diameter than the outer one, by a certain amount fixed for the special curve on which they are rolling, the axle would maintain its position radial to the curve unaided. Of course this supposition has no application to track, but the principle is applied in car wheel design and has some effect, with new wheels at any rate, toward lessening resistance on curved track. Both wheel treads are of the same diameter with respect to corresponding portions of each; but the tread of each, $2\frac{3}{4}$ ins. from the flange, is smaller in diameter than the part next the fillet by $\frac{1}{8}$ in.; that is, the wheel tread is coned $^1/_{16}$ in., as shown in Fig. 52. (The increased coning of the wheel for $1\frac{1}{4}$ ins. on the outside of the tread is to reduce the tendency of the wheel to drop between the rail heads at frog points and at the heels of frogs, and into the flared opening at the stock rails of point switches, after the wheel tread becomes hollowed out by wear.) The gage of the wheels is also made $\frac{3}{8}$ in. less than the gage of the track, permitting that much play in the wheels across the track. On a curve, then, the outer wheel, the flange of which will crowd the outer rail, will roll on a periphery of greater diameter than that upon which the other wheel is rolling, and produce the same effect as though the inside wheel was of less diameter than the outside wheel by some certain amount. As to just how much this increased diameter is, is difficult to tell, because it is not known just how far up on the flange fillet the wheel rolls, when running at any given speed. But with a new wheel the increase of diameter due to the coning, at slow speed, is at least $^1/_{50}$ in., thus enabling the outer wheel to gain $^1/_{16}$ in. on the inner wheel per revolution and hence adapting it to a curve of about $\frac{3}{4}$ deg. At higher speed the degree of curve for which this amount of coning ($^1/_{16}$ in.) would adapt itself must be larger.

By widening the gage of the rails this speed difference of outer and inner wheel is increased: for every $\frac{1}{4}$ in. the gage is widened the wheels become adapted to a curvature greater by about $\frac{1}{2}$ deg. By heavily coning the wheels the gage of the track on any curve might be so adjusted that curve resistance could practically be overcome, but neither scheme is practicable or desirable. By heavily coning the wheels more tractive power would be wasted in the increased resistance and unsteadiness of motion on tangents than would be saved on curves, unless the gage of the track on tangents corresponded to that of the wheels; and this is not a practicable proposition. For this reason wheels are coned but very little, and consequently nothing of account on this score can be gained by widening the gage of curves. The degree of curve to which a $^1/_{16}$-in. coning of the tread is adapted is so small and the coning disappears from the tread so rapidly, that, taken all in all, the part which coning of the wheels and widening of the gage plays in decreasing the resistance of wheels to rolling around curves must be very little. In fact, any advantage which accrues from the coning of wheels is soon lost, for on car and locomotive wheels which have seen much service the conicity will usually be found reversed; that is, the wheel will usually be found smaller in diameter near the flange than on the outside of the tread, thus giving exactly the opposite effect that coning is intended to produce. It has also been pointed out by Mr. M. N. Forney that coned wheels on axles held rigidly parallel do not roll as freely as a pair of coned wheels on a single axle. A model consisting of two wheels $1^7/_{16}$ and $1^5/_{16}$ ins. in diam., respectively, on the same axle rolled freely in a circle of $26\frac{3}{4}$ ins. radius. When two such models were joined together with the axles parallel and $1\frac{1}{2}$ ins. apart the combination model rolled in a circle of $33\frac{1}{2}$ ins. radius. With the axles 4 ins. apart the model rolled to a circle of 169 ins. radius, and with the axles 5 ins. apart it rolled to a circle of 322 ins, radius, showing that the tendency of coned wheels on parallel axles to roll in a circle is counteracted by spreading the axles farther apart. Reasoning from experiments with models the conclusion was reached that a freight car truck with axles 5 ft. apart and wheels coned $^5/_{16}$ in. in 3 ins. would have to be given lateral play of $\frac{3}{4}$ in. on the rails in order to roll freely to a 1-deg. curve.

There is a popular but erroneous impression that the outer wheel on curves is enabled to keep abreast of the inner wheel by a rotative slipping of one or the other, or both. It must be apparent that the action of slipping in rotation can effect no advance for either wheel, for when one wheel slips its mate must slip also. If a pair of wheels rigidly fixed to an axle which is not attached to anything be set rolling on a curve and left to themselves there will be no slipping of either wheel and the pair will not keep to the track. The outer wheel can keep abreast of the inner one only by ***swinging about it,*** and this is true whether there be only one pair of wheels, or two or more pairs joined together, as in a truck or as the connected drivers of a locomotive—the outside wheels must swing about the inside ones, and it will now be shown how this occurs.

Referring again to the pair of wheels pushed lawn-mower-fashion (Engr. *G*), suppose that no attempt is made to keep the axle radial to the curve and that the wheels are pushed forward apace. It will soon be seen that the inner wheel has gained a little on the outer one with respect to a radial line (*A C*) drawn to the outside wheel in its new position. The wheels have run equal distances, but not straight ahead; the axle in its new position is parallel to its old position; and with respect to the curve the handle has swung inward. This fact goes to show that in order to keep the axle always radial to the curve, or at a constant angle with a radial line, there must be a force outward at the end of the handle



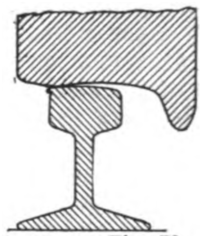


Fig. 52.—M. C. B. Standard Wheel Tread and Flange. Fig. 53.

to oppose the inward swing; or, in other words, the tendency of the axle to swing out of a radial direction, or out of a position having some constant angle with the radial direction, exerts a force tending to swing the handle inward with respect to the curve. Now this is exactly the action of the front wheels and axle in any four-wheel truck. In place of the handle there is the truck frame attached to both axles, holding them parallel to each other and rectangular to itself. In place of the hand guiding the handle or frame, as in the lawn-mower affair, the trailing wheels and axle hold the rear part of the frame to a position constant in direction with respect to the curve, or at least very nearly so (see Engr. *R*). The force which, with the single pair, swung the handle inward still acts and tends to swing the rear pair of wheels inward. This accounts for the fact that in passing around curves the front outer wheel of the truck crowds against the rail continually, while with the rear wheels the tendency appears as though to crowd the pair toward the inner rail.

Aside from the swinging force exerted on the truck by the tendency of the front axle to move parallel to itself, another partial cause for the inward swing of the rear axle is a considerable force tending to swing the truck as a whole, which is due to the retardation of the front outer wheel in consequence of the friction of its flange against the rail. The tendency of movement of the wheels on the rear axle is the same as that of the front pair, namely, to run straight ahead and follow the forward pair, but the motion of the outer rear wheel is not in a direction to crowd the outer rail at the point of contact (Engr. *R*). Any inward swing of the rear axle moves it into a position approaching that of a line radial to the curve. With the axle radial the movement of the wheels is, of course, neutral respecting the two rails; that is, they tend to crowd neither rail. Hence it occurs that every force acting upon the rear axle which can affect its position with respect to the curve tends to cause the outer rear wheel to run clear of the outer rail. Observation of a train passing a curve will show that the flange of the rear inner wheel on some of the trucks crowds the inner rail, while in other cases the rear wheels take an intermediate position respecting the rails. According to Mr. Wellington the flange of the outer rear wheel of a four-wheel truck is supposed to stand away from the outer rail a distance equal to the versed sine of a chord having twice the length of the wheel base. This is the same as saying that the rear axle maintains a position radial to the curve, if free to do so; but he gives no reason why this should necessarily be the case. As the shape of the wheel tread must be an important factor of the behavior of the wheel on the rail one can readily understand how the position of the rear wheels relatively to the rails is not fixed, as is proved by observation. It is readily imaginable how a pair of trailing wheels the treads of which are in a condition of reversed conicity might take a position different from that of a pair of wheels newly coned. The degree of the curve, the elevation of the outer rail and the length of the wheel base are also effective on the behavior of the trailing pair of wheels. Other conditions remaining the same, the shorter the wheel base the closer should the flange of the inside wheel on the rear axle run to the inside rail. And then, it might be expected that the position of the rear wheels of a truck would be quite dependent upon the relative freedom of action under the side bearings. Where the body bolster is down hard on the side bearings the truck may not be free to align itself in accordance with the tendency of the wheels.

It is now opportune to consider how both outer wheels of a four-wheel truck do actually swing about the inner wheels and keep abreast of them on the curve, or how the truck as a whole is guided or kept straight with the track. With a four-wheel truck standing on the track so that the flanges of both outer wheels touch the rail neither axle can be radial to the curve, because radii cannot be parallel. In this position a line drawn parallel to the axles half way between them is radial to the curve (*A C*, Engr. *R*), and the position of each axle deviates from that of a radial line by a very small angle which varies with the degree of the curve. The nearer the truck can be kept to this position the less will be the resistance to its movement. Start the truck around the curve. Immediately both inner wheels turn equally with those on the outside, and will run an equal distance (neglecting the effect of coning) unless held back; but they are held back. The tendency of the leading inner wheel to get farther away from, and of the rear inner wheel to approach, a line radial to the curve swings the trailing pair of wheels inward to the curve about the outer front wheel as a center (for the instant). Of course the limit of this movement is when the inner rear wheel flange meets the rail, and frequently a truck will be seen running in this way, as already stated. There being no external force exerted to move the leading wheels and axle laterally or in a direction endwise to the axle, the outer leading wheel always tends to roll straight ahead and its flange, of course, cannot depart from the rail.

The truck moves continually in a position askew to the curve, being so compelled by the constant tendency of the inner wheels to outrun the outer ones with respect to a line drawn radial to the curve. The truck, as a whole, swings about its inner rear corner as a center—that is, about the point where the inside rear wheel touches the rail. As the two sides of the curve are unequal in length the outer wheels must swing through the distance necessary to keep them opposite their mates on the inner rail, the tendency of which is to keep in the advance. Hence in passing around a curve the whole load on the outer wheels must be dragged a distance equal to the difference in the length of the two sides of the curve. The action which causes the truck to swing is the lateral sliding of the front wheels across the rails toward the inside of the curve, due to the constraint of the outer front wheel flange. In Engraving *S*, Fig. 51, the four corners of the rectangle *a, b, c, d* represent diagrammatically the points of contact of the four wheels of a car truck with the rails, *a* and *b* being the points of contact of the leading pair of wheels and *c* and *d* those of the trailing pair. If *b* be pushed or shoved in the direction of *a*, then *a* must move also in that direction; and the side *b d* of the rectangle will be moved ahead or swung around *c* as a center, and the direction of the truck will be changed by the angle *a c a'*. This lateral sliding of the leading pair of wheels is caused by the circular path to which the wheels are constrained. The wheels at any instant actually move in a different direction from that of the plane of their rotation. The movement is the resultant of a lateral skidding combined with longitudinal progression. In order that the truck may curve, both the outer wheels must slide along the rail and both leading wheels must slide laterally; the outer leading wheel therefore slides both longitudinally and laterally respecting the rail. What is true of the action of a single truck applies to both trucks of a car and to the trucks of all the cars in a train. The effect of the "indraught" of the locomotive—that is, the tendency in the pull of the locomotive to straighten the train—in reducing the crowding action of the front outer wheel flanges against the rail is not perceptible, even in the longest train. The front outer wheel of a car or truck persists in flanging with the outer rail against all forces acting upon the car in consequence of being coupled in a train.

The tendency of the two wheels on the front axle to run straight ahead crowds the flange of the outer wheel hard against the rail, and the wheel is continually tending to roll on the fillet or side of the flange and lift the tread from the rail. At slow speed, when the rails are dry, the wheel on the outer rail may sometimes be seen to rise and roll along on the fillet or side of the flange, while the inner wheel may be seen to spread or spring slightly outward the top of the inner rail; until suddenly the wheel on the outer rail will drop down to a bearing on its tread and, by this wedging-like action of its flange, transmitted through the axle, shove the inner wheel squarely across the top of the inner rail; this rail, as soon as the wheel lets go, tilts suddenly back to its normal position. The tendency of the wheels is thus to spread the rails apart. A movement of the inner rail relatively to the inner wheel a full $\frac{1}{4}$ in. has been observed to suddenly take place at slow speed. At higher speeds both the rail and the wheels move relatively just the same, in a direction crosswise the track, but more continually, and with an amplitude decreasing with increase of speed, until a point is reached when both the inner wheel and the top of inner rail are in a state of continual vibration back and forth. At good speed the outer front wheel will sometimes roll on the fillet or side of the flange, with the tread lifted clear of the rail, for long distances. The path of contact of the inner wheel with the rail is a zigzag line like that shown in Engr. *N*, Fig. 51, exaggerated and distorted for sake of clearness. The portion *a b* is supposed to be a movement in the direction of the rotation of the wheel, and the shorter portion, *b c*, the movement across the rail top. The arrow denotes the direction in which the wheel is moving. This vibration of the inner wheel sometimes sets up a ringing sound not unlike the squealing of a pig, but it varies in pitch all the way from a coarse, grating sound to a howl, and up to a sharp or shrill ring. The explanation of this phenomenon is that the wheel is in principle a flattened-out bell kept in continual vibration by the rapid alternate catching and slipping of its tread in contact with the rail.

Canting of the Inner Rail.—The action of wheels on curves enables one to account for the canting or tilting of the inside rail. On curves where the ties are soft or old the inside rail will sometimes cant or tilt over, more or less, the top of the rail canting outward; and frequently it will spread the spikes. This action is most pronounced where the traffic is heavy and speeds, as a general thing, are slow. Some students of the question attempt to explain it on the claim that the increased weight which the inside rail sustains at slow speed causes the canting and that the spreading is caused by the tight running of locomotive wheel bases on track not gaged widely enough. There is, on elevated curves, at slow speed, an increased weight borne by the inside rail over what it sustains at higher speeds, and the greater weight thrown to that side increases the friction between the wheels and the rail and consequently the force of the overturning component on the inside rail; and there is a corresponding decrease in the overturning force on the outside rail. This overturning force is greatest when the car is standing still, because when in motion it is counteracted by centrifugal force, more or less, and may be entirely overcome. The principal cause of canting, and which is independent of centrifugal force, is the lateral sliding of the inner wheel across the rail top, as hitherto explained. Its effect is somewhat dependent upon the elevation of the outside rail and the speed, because the greater the weight which is thrown upon the inside wheel the greater will be its tendency to travel tangent to the curve and the greater the skidding friction. When it is considered that while a long freight train is passing around a curve all the inside wheels on that curve are exerting a reactionary crowding force across the top of the inside rail it is not difficult to understand how it is tilted outward, and the phenomenon is explained.

It may be asked why the outside rail is not tilted outward, inasmuch as it would seem that both outside and inside wheels must crowd outward across the rails with the same force tending to spread them apart, the action of each and the reaction of the rail against each, being equal and opposite in direction. Against the head of the outside rail there is acting a force due to the crowding of two wheels on each axle, but (leaving for the moment centrifugal force due to speed out of the question) the crowding of the flange of the outside wheel alone is a binding action, taking place simply between the tread, flange and rail; and, having no reaction against any object exterior to the rail, it cannot exert a force tending to overturn that rail. The tendency of the outside wheel and flange is to continually run tangent to the curve and against the rail. The tendency of the inside wheel, on the contrary, is to run tangent to the curve, but away from the inner rail. It is this tendency of the inside wheel to run away from its rail which produces a lateral force through the axle tending to overturn the outside rail, because it is reacted against by an object exterior to that rail; and the object reacting against this lateral force is the inside rail, so that the same force acts equally against both rails. In other words, the force exerted by both wheels, in being turned from a straight path and constrained to a curved path, as far as it can act toward overturning either rail, must tend to overturn both rails with the same force. It is also clear that this force can be no greater than the friction between the inside wheel and the rail top; that is, the friction opposing the lateral sliding of the wheel across the rail. The fact, then, that the outside wheel acts against the side or corner of the outer rail head by flange pressure, while the inside wheel acts against the inner rail only by sliding friction between tread and rail top, does not render the outside rail the more liable to overturning. Just why the flange pressure from the outside wheel alone has no tendency to overturn the outside rail may be more clearly understood, perhaps, if it is reflected that, with some means to steady it, a single wheel, not attached to an axle, will roll along the outside rail and keep to the rail. The flange will, of course, crowd the rail, but, as the wheel can react against nothing exterior to the rail, it can at slow speed have no tendency to overturn the rail. On the other hand, a wheel rolled similarly along the inside rail, having no axle or other thing to react against, would not keep to the rail, for it would roll straight ahead, of course. So much for the front pair of wheels. But with the rear pair of wheels the case is different. As has been shown, the rear pair of wheels serve to guide or steer the truck frame straight with the track; and the tendency of the front axle to skew swings the rear end of the frame so as to oppose the tendency of the rear axle in an endwise direction, sufficiently, almost always, to keep the flange of the outer rear wheel from crowding the rail. In exerting a force outward to the curve, by which the rear wheels and axle oppose and balance the inward swing of the rear of the truck frame, the wheels must necessarily react against something exterior to the frame, and that which they react against is the two rails. In other words, and to use a familiar picture, for illustration, the force exerted by the tendency of the inside rear wheel to run away from the rail, reacts outwardly against that rail and exerts itself in crowding against the rear of the truck frame as a man would in "beaming" a plow. Likewise, the force exerted by the outside wheel is also a force crowding against the frame, but reacting against the outer rail in a direction inward to the track or curve. Thus, while the reaction of the front pair of wheels against the rails has a tendency to spread the rails apart, the tendency of the reaction of the rear pair against the rails is to overturn both those rails, not in opposite directions, so as to spread them apart, but in the same direction, and that toward the inside of the curve. If the force required to keep the truck gradually swinging, as it moves along the curve, be greater than this tendency of both the rear wheels, the flange of the inside wheel will seek its rail; if such required force should be equal, the rear wheels will take a mid position respecting the two rails; while if it should be less, the outside rear wheel flange will crowd the rail. As stated, however, such last condition is not usually the case with a truck of ordinary length. So, regarding the tendency of the rear pair of wheels to run in a straight line, the reaction of the inner wheel is always against the rail, tending to spread it or overturn it outward to the track. With the outer rear wheel, if its flange be not against the rail, its tendency to run straight ahead is exerted as if to overturn the outer rail inward to the track, and it thus balances the force exerted on the rail at the outer front wheel in the outward direction. The resultant overturning force against the outer rail thus becomes nil, while the crowding effect of these two forces forms a couple tending to move the rail both out and in—outward at the front wheel and inward at the rear wheel. In no case, except in the very exceptional one where the outer rear wheel flanges with the rail, can there be any resultant overturning force acting on the outer rail, and even in that case it would but little exceed that of the front pair of wheels. To sum up, then, the combined resistance offered by both inner wheels, to being constrained to keep their positions opposite the outer wheels, relatively to the track, in traveling a curved path, acts with full effect, at all speeds, toward overturning the inside rail outward; while with the outside rail it is only the very exceptional case where there is any resultant overturning force against it at all. Hence it is that at slow speed the inner rail is sometimes tilted while the outer rail is not.

The manner in which the wheels bear upon the rails will also account in some measure for the unequal tendency of the inner and outer rails to tilting. The manner of bearing is indicated by the rail wear. Thus the top of the outer rail wears down most rapidly at the gage side of the head, showing that the preponderance of weight bears upon that side, at least until the rail becomes considerably worn, the effect of which is an unequal distribution of the weight on the rail base and a tendency to tilt the rail inward to the track. On the inner rail, however, one will usually find the wear most rapid on the outside of the head, caused by the bearing from the least worn portion of the wheel tread, as shown in Fig. 53. The tilting effect due to the unequal distribution of weight in this case is toward the outside of the track, or in the characteristic direction for the inner rail. It may be noted in passing that a condition favorable to the bearing of the wheel in the manner shown is widened gage, since it permits more lateral movement in the wheel. Another commonly observed effect from this manner of wheel bearing is the flowing of metal and the formation of "fins" along the edges of the rail top.

There is, nevertheless, a force having an overturning tendency upon the outside rail, namely, centrifugal force, due to speed. For any given speed there is always a certain amount of outward force exerted by a body traveling a curved path, such force being due to the persistence of the body in tending to travel in a straight line. In curved track without elevation all this force is exerted against the outer rail of the curve. For any given speed this force against the outer rail may be overcome by elevating the outer rail, so that a horizontal component of the force of gravitation caused by the tendency of the load to slide in the direction of the inclination of the track, will balance it. As is discussed in connection with the subject of curve elevation, this balancing can be accomplished for but one speed only, so that at higher speeds than the one calculated upon some overbalance of centrifugal force will still act against the outer rail; but at slower speeds, for which the elevation is excessive, the horizontal component of the force of gravitation overbalances the centrifugal force and the resulting force becomes centripetal, or against the inner rail.

The forces acting against the rails have thus far been spoken of as having an overturning effect. Such is the tendency, but the extent to which overturning or tilting of the rail actually occurs depends largely upon the condition of the ties. The inside rail is subject to both tilting and spreading, the former more especially after the ties become somewhat unsound. The outside rail is subject to spreading but seldom or never to tilting, the reason being, perhaps, that while the force which causes the spreading of the outside rail—the centrifugal force—is acting with maximum effect at high speeds, at the same time also the weight or forces acting vertically downward upon the rail have been largely increased, because the centrifugal force acting upon the upper (and heavier) portions of the car and its load tends to relieve the inside wheels of load and throw it upon the outside ones. Also, any tilting outward of the car body on its springs actually moves the center of gravity of the load nearer the outside wheels. Resistance to spreading is the resistance offered by the spikes and the friction between tie face and rail base; while resistance to overturning or tilting is weight to be actually lifted; for, in being tilted, the rail must revolve about one corner of its flange and thus cause the inner corner of the head to rise. If the weight or force acting vertically downward be great relatively to the outward or centrifugal force the resultant force acting on the rail may fall within the outer corner of the base, thus operating to increase the stability of the rail instead of producing an overturning effect. This action may be understood by referring to Engr. *T*, Fig. 51. If *A B* represents the direction and intensity of the force due to the weight of the wheel and its load, and *C B* the direction and intensity of the centrifugal force, the resultant force acting on the rail will be indicated in direction and intensity by the line *E B*. If this line produced falls within the corner *D*, as at *F*, there can be no overturning tendency; but if the two forces acting were in the ratio of *A'B* to *C'B*, then the resultant *E'B* produced would fall without *D*, and an overturning tendency would result.

In what has been said with reference to the wheel flange, it has been supposed to be of standard form and not worn. A section of the Master Car Builders' standard wheel tread and flange is shown in Fig. 52. It will be noticed that the flange slopes away from the tread by a gradual curve or fillet, the object being to avoid having the flange make with the rail a surface contact. The greater the surface between the parts in contact, the greater is the grinding action between the two. There is also another reason for having a curve of comparatively long radius between the tread and flange. It has been stated that the front axle of any wheel base or truck must run askew to the rails when passing around a curve. Now, with the axle in this position, with the wheel flange against the head of the outside rail, suppose that a vertical plane be passed through the axis of the axle and the point where the tread meets the rail head. It must be seen that the shape of the flange determines whether or not the point where the flange touches the rail lies in this plane or outside of it. Suppose, for sake of illustration, that the flange is perpendicular to the tread, or that it is in shape the reverse of the rail head, as it practically does become when badly worn. Place the axle radial to the curve, with the flange of the outside wheel against the rail head. A plane passed as stated will now contain the points of contact of both tread and flange. But swing the axle into a skewed position, as it must take when running, and it will be seen that effectually the wheel is rolling with the outer edge of the flange grinding against the rail at a point some few inches in advance of the vertical plane in which lie the axis of the axle and point of contact of the tread; in short, the flange touches the rail at a point in advance of that at which the tread touches, and consequently the wheel makes contact with the rail by parts of unequal diameters. To properly understand the increased resistance caused by this action consider that the force exerted by the locomotive in hauling a car wheel acts about the point of contact of tread and rail with a lever arm equal to the radius of the wheel, and that just so far as the flange meets the rail in advance of this point, with just that length of lever arm is the friction of the flange against the rail acting against the force exerted to roll the wheel.

It is well known that enormous resistance is offered by car wheels with flanges which meet the tread more or less squarely. The flange, meeting the rail in advance of the point where the tread does, makes contact at a periphery of larger diameter, and produces an effect similar to that which would obtain if the wheel was skidding a block or chock in front of itself. But a well-shaped flange, which curves gradually back from the tread, cannot come into contact with the rail far in advance of a plane containing the axis of the axle and point of contact of tread, and so whatever friction exists between flange and rail has a very small lever arm with which to oppose the force which is rolling the wheel. When the wheel is rolling partly on the tread and partly on the side of its flange there is, of course, in any case, some grinding action of the flange against the rail, owing to the differing diameters of the parts of the wheel in contact; but if the wheel is rolling on the side of its flange against the corner of the rail head there is no grinding and consequently no opposition to the rolling of the wheel.

Widening Gage on Curves.—In connection with the action of car wheels on curves arises also the question of widening the gage. Since the standard wheel gage is $\frac{3}{8}$ in. less than the gage of the track it is impossible for the flanges of both wheels on the same axle to crowd both rails, and therefore impossible for a four-wheel truck to bind in any curve used in steam railway track. It must therefore be clear that there is not the slightest necessity for widening gage for four-wheel trucks. The question regarding the widening of gage on curves must arise with vehicles having more than four wheels in the same base, especially as is the case with locomotives having six or more drivers.

The question of widening gage on curves involves a discussion of two features of locomotive running gear, namely, the arrangement as to the flanging of the driving wheels, and the design of the forward truck respecting provision for lateral movement of the locomotive frame. As to either of these matters there is as yet no widely prevailing settled understanding between the track and motive-power departments. The wheel base details of the locomotives on each railway are usually designed to suit the ideas of the motive-power management respecting the features here considered, and the official responsible for the maintenance of the track studies the conditions of running as they appear in the spreading of the rails and in rail wear, and then adopts some try-and-fit rule for gaging the curves. To summarize the situation generally, it may be said that it is not customary for the two departments concerned to study the matter from a mutual point of view.

In considering the matter of driving wheel flanges it is well to begin with a case which fairly approaches the extreme of ordinary conditions. The longest driving-wheel base used to an extent which might be termed general is that of consolidation, and mastodon or 12-wheel locomotives, measuring 16 ft. Let it be supposed that the rails and wheel tires are new or not worn and that the rails are laid snug to gage, and then ascertain how much, if any, the gage should be widened in order to pass such a driving base freely around a sharp curve, the total wheel base (which includes the forward truck) not being considered in this instance. On a 15-deg. curve the middle ordinate of a 16-ft. chord is almost exactly 1 in., and a side ordinate corresponding to the position of one of the intermediate drivers is $^{57}/_{64}$ in. Taking account of the usual $\frac{1}{8}$ in. of side play in the journal boxes (it is frequently as much as $\frac{1}{4}$ in., and sometimes more, in new locomotives), it is clear that if the tires of the two intermediate drivers are flanged, the flanges of these wheels must stand at least $^{49}/_{64}$ in. clear of the outer rail and 4 ft. $7^{47}/_{64}$ ins. from the gage side of the inner rail. But the gage of the wheels is 4 ft. $8\frac{1}{8}$

ins., or $^{25}/_{64}$ in. more than the available room. Apparently, then, the gage of the track should be widened $^{25}/_{64}$ in. or about $\frac{3}{8}$ in.

Under ordinary conditions, however, it would not be necessary to widen the gage that much, for it is quite commonly the practice to make the gage of the front and rear pairs of drivers $\frac{1}{4}$ to $\frac{3}{8}$ in. less and the gage of the intermediate pairs of drivers $\frac{1}{8}$ in. less than standard, without extra side play in the axle boxes. If such was done in the case here considered the required amount of widening of the track gage would be reduced to $^{13}/_{64}$ in. By a "tight squeeze" this wheel base might pass safely around the curve without widening the gage, but the wheels would either ride high on their flanges or else some springing of the parts (such as the rails or the locomotive frame) would have to take place. With rails or wheels considerably worn, however, such a wheel base should freely pass the curve referred to. It takes but little wear at the corner of the rail head and in the fillet of the wheel flanges to increase the free side play of the wheels to $\frac{3}{4}$ in. In fact, one can find but few wheels, even among those considered to be in good condition, with which the side play is less than 1 in. on rails laid to standard gage. With new rails or rails not worn at the top corner of the head, it would seem advisable to widen the gage of the curve for such a wheel base as is above considered.

On a 10-deg. curve the middle ordinate of a 16-ft. chord is $^{11}/_{16}$ in., and a side ordinate at one of the intermediate drivers about $^{39}/_{64}$ in. Taking into consideration the $\frac{1}{8}$-in. side play in the journal boxes and the $\frac{3}{8}$ in. in the wheel flanges, as before, we find the required amount of widening of the gage to be $^{7}/_{64}$ in.; on an $8\frac{1}{2}$-deg. curve the wheel base under consideration would just pass around the curve freely without widening the gage. Substituting a set of six-coupled flanged drivers, with the usual wheel base of 14 ft., for the eight-coupled set already considered, and assuming similar conditions of side play, the required amount of widening of the gage for a 15-deg. curve is found to be $^{9}/_{32}$ in.; on a $9\frac{3}{4}$-deg. curve the wheels will just pass freely without widening the gage.

In considering the length of driving base on very sharp curves the measurement should extend to the point of contact of the wheel flange, which is some little distance beyond the point of contact of the tread. In other words, on very sharp curvature the length of the driving base exceeds the distance between centers of front and rear axles by the length of the lap to the contact points of the flanges. On main-track curves this length of lap need not be considered, but on some side-tracks it is a matter requiring attention, as the length which it adds to the effective wheel base causes binding in the curves. This lap extension of the wheel base occurs on all curves with sharply-worn flanges, but in ordinary cases the wear of the flanges is sufficient allowance for the extra length of base produced. Another instance in which it is important to take account of the lap of the wheel flanges is in considering the width of flangeway at guard rails on sharp curves.

It is entirely clear that with flangeless, "blind," "bald" or "plain" tires (as they are variously known) on the intermediate drivers in the foregoing examples no widening of the gage would be required; that is, so far as the driving base alone is considered. And really, for roads of sharp curvature there is no necessity for more than two flanged drivers on each side of ordinary locomotives, for not more than that number can flange with the rail on curves sharper than about 5 deg. for a 14-ft. wheel base and about 4 deg. for a 16-ft. base, even when $\frac{1}{8}$ in. is allowed for side play in the boxes and $\frac{1}{8}$ in. more for the set-in of the leading and trailing driving tires, or half the amount by which the gage of the intermediate drivers exceeds that of the forward and rear pairs. With all but four of the drivers flangeless the question of widening the gage on curves then depends upon the manner in which the locomotive frame is attached to the pilot truck (and in some cases the trailing truck).

In this country locomotives are classified according to the number of driving wheels and truck wheels, and the following is a description of the types most commonly in use:

American or 8-wheel,	4	drivers	and	4	pilot truck	wheels.
Mogul,	6	"	"	2	" "	"
10-Wheel,	6	"	"	4	" "	"
Consolidation,	8	"	"	2	" "	"
Mastodon,	8	"	"	4	" "	"
Decapod,	10	"	"	2	" "	"

Atlantic,	4	drivers,	4	pilot truck wheels,	2	trailing	wheels.
Chautauqua,	4	"	4	" " "	2	"	"
Prairie.	6	"	2	" " "	2	"	"
Pacific	6	"	4	" " "	2	"	"
Mikado,	8	"	2	" " "	2	"	"
Trailer Decapod,	10	"	2	" " "	2	"	"

A pilot truck of two wheels is called a "pony" truck and one of four wheels a "bogie" truck. Respecting its connection with the frame, a bogie may be either a "rigid-center" or "swing-center" truck. The former arrangement is where the frame is so pivoted to the truck that there can be no lateral movement, any more than is usually allowed in journal boxes. The swing-center arrangement is one whereby the frame is attached to the truck by means of swinging hangers, which permit lateral motion of a few inches in the front end of the frame. A pony truck must necessarily be of the swing-center pattern. It is guided by a "radius bar" pivoted at a point near the forward end of the driving base, which keeps the axle radial to the curve, and in this respect its similarity of movement to that of a lawn mower is striking, as hereinbefore alluded to. Swing-motion devices take various forms, but the most frequent arrangement is to support the center casting on four links of 6 to 9 ins. length, usually splayed or hung out of the vertical, so that they will not swing too freely on straight track. In other cases "controlling" springs are set to oppose the sway of the links, the tension being such that a side pressure of 1 to 1½ tons must develop before lateral motion of the frame can take place. These springs serve to steady the motion of the engine on straight track but do not prevent the desired lateral swing on curves. Lately the use of heart-shaped or "three-point" hangers seems to be gaining favor. This style of hanger in its normal position hangs upon two points of support, at the top, the load being carried at the bottom from a point central to the two upper supports, thus maintaining stable equilibrium, as in the case with diagonally-hung links. As the hanger moves to either side it swings clear of one of the upper supports and the effect of a diagonally-hung link is immediately produced. As the ordinary link hanger swings from the vertical it offers more and more resistance to swaying as it swings farther out, and does, therefore, in a measure, enable the truck to do something toward guiding the engine. The chief advantage with the three-point device is that all of the hangers supporting the center casting swing parallel, thus equally distributing the load and the resistance to swaying; and therefore the part which the hangers take in the guiding of the engine is very considerable from the instant lateral motion begins; whereas, with the ordinary link hanger the guiding action does not become important until the hanger has swung far out of the vertical.

The pilot truck of a locomotive may serve two purposes: (1) It supports part of the weight of the locomotive, but (2) it may or may not guide the forward end of the frame. In the locomotive wheel base, as in the four-wheel truck, the flange of some one wheel must do the entire work of guiding all the rigidly connected wheels around sharp curves. One object of the pilot truck may, therefore, be to keep the front driver flange from the rail. As the rigid-center truck is fixed so as to swivel only, it accomplishes this by force exerted through the center pin of the truck. While the swiveling of the truck obviates to a considerable extent the grinding action of the front outer wheel flange against the rail, still the pressure of that flange against the rail is greater than is due merely to the load carried by the truck, for it must serve to guide the whole base, driving wheels and all. (This statement and a preceding one to the same effect may not be strictly correct in all cases. For instance, it might occur that with a locomotive concentrating an undue proportion of its weight on the driving wheels the force exerted by the resistance of the driving wheels to being guided with the curve would hold both outer pilot wheel flanges to the rail in spite of the tendency in the truck to swing the rear wheel away from the rail. In a case of this kind the flanges of both truck wheels would necessarily take part in the work of doing the guiding.) It is not considered good practice to allow sufficient side play in the truck journal boxes to permit the forward driver, if flanged, to assist in the work of guiding, because an abnormal amount of side play in the truck allows too much swinging of the frame when the locomotive is pulling hard on tangents.

The swing-center truck principally bears up weight, and takes but comparatively little or no part in guiding or swinging the driving base, except within certain limits. It does, of course, as already shown, exert a guiding influence to the extent of the resistance of the forward end of the frame to sway on the hangers, and in the case of a pony truck its resistance to being turned by the radius bar places some restraint on the outward tendency of the front drivers; but, in the main, the first flanged driver must guide not only the driving base but the locomotive entire. With a swing-center pilot truck the front driver is nearly always flanged, because it is the one which can operate with the longest leverage to force the base around. It will readily be seen that if the front driver is blind, the next driver behind must crowd the rail with much greater force in order to keep the wheel base swinging with the curve, than would be the case if the front driver did the guiding, because it not only is operating on less leverage to swing itself and the drivers following, but has also to swing the driver in front of it on the principle of a force acting on a lever of the third class; that is, the force acts between the fulcrum and the load. Even at the front driver there is required a much greater crowding force than at the pilot truck, to produce the same turning effect on the locomotive, owing to the fact that the frame projects some distance ahead of the drivers. It ought to follow, then, that the nearer the guiding flange can be to the front of the locomotive the less will be the wear on flange and rail and the less the tendency of the locomotive to spread the outer rail. This would seem to be a point in favor of the rigid-center pilot truck respecting the relative ease of service on curves.

Having investigated the behavior of the driving and truck wheels separately it now remains to consider the action of these two sets of wheels taken together. The wheel base of a locomotive includes, of course, both the driving wheels and the truck wheels. The rigid wheel base includes such wheels as are connected with the locomotive in a manner not to permit side swinging of the frame (play in the axle boxes excepted). On a locomotive with a swing-center pilot truck the rigid wheel base comprises only the driving wheels. Such is necessarily the case with all mogul and consolidation locomotives. On a locomotive with rigid-center pilot truck the limits of rigidity are the center pin of the truck and the axle of the rear drivers. It should be noted that such does not cover the total wheel base of the locomotive, because the truck is free to swivel into line (that is, into its natural position) with the curve. For convenience of reference the distance from rear driving axle to the center of a bogie truck will be called the *long base;* the corresponding distance where a pony truck is used is, of course, the total wheel base.

The question of widening the gage of curves is easily answered in any case, and the amount of widening may be determined either by computation or graphically. By applying the rectangle of the rigid wheel base of each type of locomotive to a diagram of the curve the ruling type is at once discoverable and the proper amount of widening may be scaled off, or it may be computed from the chords and ordinates. For the purpose of direct calculation of limiting curvature passable by six or eight flanged wheels, and the amount of widening required for stated conditions of wheel base and curvature, Mr. Wm. H. Searles has worked out formulas of convenient application. In the case of three pairs of flanged wheels in the same rigid base the limiting curvature on which the wheels will run without widening the gage is expressed by the formula

$$D = \frac{3825\ p}{l^2}$$

in which D represents the degree of curve sought, p the flange play in inches, and l the length of the rigid wheel base in feet. If the intermediate axle be not at the middle of the base let the distance from it to the two end axles be represented by a and b, in feet. The limit of curvature then becomes

$$D = \frac{956\ p}{a\ b}$$

In the case of eight flanged wheels in the same rigid base the formula is applicable by considering the intermediate axle nearest the middle and ignoring the other.

In the case of a locomotive with a swing-center truck and not more than four flanged drivers the limiting degree of curve that will pass the engine without widening the gage is expressed by the formula

$$D = \frac{956}{a\ b}\left(p + \frac{b\ s}{a + b}\right),$$

in which a represents the distance in feet from center of truck to axle of the leading pair of flanged drivers, b the distance in feet between the axles of the two pairs of flanged drivers, p the play at the flanges in inches, and s the side motion of the swing hangers from center, in inches. The total clearance required to pass an engine through any curvature, the degree of which is represented by D, is found by the formula

$$P = \frac{D\ a\ b}{956} - \frac{b\ s}{a + b}$$

To find the amount of widening required subtract from P the play at the flanges; that is, *widening of gage* $= P - p$. This formula is general and applies to a single rigid base as well as to a locomotive with swing-center truck. In the case of a rigid-center truck or in that of a single rigid base s becomes zero and the last term of the equation disappears. For curvature of 20 deg. or more the numerical coefficient in the above formulas should be 960 instead of 956; for 30 deg. it should be 966.

Bearing in mind, then, that the matter of widening the gage of curves on any road is a special problem to be solved from the data of the locomotives in service, it may nevertheless prove instructive to investigate in a general way a common example of each type of wheel base. In every case the gage of the wheels will be taken at the standard 4 ft. 8½ ins. and the side play in the axle boxes ⅛ in.; in the case of swing-center trucks the permissible sway will be assumed at 3 ins. from center. This amount of lateral movement has been found to take place on a number of roads. The most common example of American or 8-wheel locomotive has a driving base of 8½ ft. and a long base of about 20½ ft. For this engine with a swing-center truck it is unnecessary to widen the gage on curves not sharper than 16½ deg.; but if the truck has a rigid center the sharpest curvature on which the engine will run freely without widening the gage is 4½ deg.

The average driving-wheel base of mogul locomotives seems to be about 15 ft. and the average total wheel base of engine about 23 ft. On engines of this class the pilot truck is of the radial swing-center type and the forward driver must do the guiding, and therefore that driver should be flanged. With the middle drivers flangeless there is no necessity for widening the gage of curves not sharper than 19½ deg., but with all of the drivers flanged the sharpest curvature on which the engine will run freely without widening the gage is 8½ deg. A 6-coupled switching engine without truck behaves on curves like a mogul with unlimited sway on the pilot truck, but as the wheel base is usually but 11 to 12 ft. in length it is not necessary, even if all the drivers are flanged, to widen the gage of curves not sharper than 13 deg. (for 12-ft. base) to 16 deg. (for 11-ft. base). The Columbian type of locomotive, which has four coupled drivers with a pony radial truck in front and a pair of trailers behind, behaves on curves like a mogul; unless the trailing truck should be swing center or provided with excessive lateral play in the boxes, in which case it would behave like an 8-wheel engine with swing-center pilot truck.

The average driving base of 10-wheel locomotives is 14 ft. and the average long base is 21 ft. 9 ins. With swing-center pilot truck and the middle or main drivers flangeless the gage of curves not sharper than 21½ deg. need not be widened; with all the drivers flanged the gage of curves exceeding 9½ deg. should be widened. With a rigid-center truck no advantage to speak of is gained by omitting the flanges on any of the drivers, as with the leading drivers flangeless, or with the main drivers flangeless, or with all drivers flanged, the sharpest curvature on which the engine will run freely without widening the gage, in any of the three cases, is 4 to 4½ deg. The Atlantic type of passenger engine, which has four coupled drivers with a bogie truck and a pair of trailing wheels, may be considered a 10-wheeler, so far as the matter of taking curves and the widening of gage are concerned; unless the trailing truck should be radial and swing center (Chautauqua type) or have excessive lateral play in the boxes, in which case it would behave like an 8-wheel engine.

An ordinary (although seldom exceeded) driving-wheel base for consolidation locomotives is 16 ft., with a total wheel base for the engine of 24 ft. As the truck in this case is of the radial or swing-center type the front driver is flanged and must do the guiding. With bald tires on the intermediate drivers the gage need not be widened for this engine unless the curvature exceeds 18½ deg., but if all the drivers are flanged the gage should be widened on curves sharper than 8½ deg. No advantage is gained by omitting the flanges on only one pair of intermediate drivers. The prairie type of locomotive, which has six driving wheels with a pony radial pilot truck, besides a pair of trailing wheels, behaves on curves like a consolidation engine; unless the trailing truck should be radial and swing center (as it is in some cases) or provided with excessive lateral play in the boxes, in which case it would behave like a mogul.

The average driving-wheel base of 12-wheel or mastodon locomotives is 15½ ft. and the average long base is 23 ft. With a swing-center pilot truck and the intermediate drivers blind tired the gage of curves not sharper than 20½ deg. need not be widened, but with the same truck and all the drivers flanged the gage should be widened on curves sharper than 9 deg. No advantage is gained by omitting the flanges on only one pair of intermediate drivers. With a rigid-center truck the second or main driver comes nearest the middle of the rigid wheel base and it should have the blind tire; and, thus arranged, the gage should be widened on curves sharper than 4 deg. Although a flange on the front driver of this engine with a rigid-center truck is not a necessity, still nothing is gained in freedom of movement by omitting it, because that driver is farther from the center of the rigid wheel base than the driver following. Neither is anything gained by omitting the flange of the third driver when there is a rigid-center truck, because it is farther from the middle of the rigid wheel base than the first driver, the flange on which should be retained if the flange of the second driver is dispensed with. With all the wheels on this engine flanged the sharpest curvature on which it will run freely without widening the gage is 3¾ deg.

From the foregoing it will be seen that as between the various types of locomotives having rigid-center pilot trucks and all drivers flanged there is but little choice, 4 deg. being about the sharpest curvature any such locomotive will run around freely without widening the gage. As to the location of the flangeless drivers there is no uniformity in general practice, the flanges in some cases being omitted from one or more pairs of the intermediate drivers and in other cases from the front pair. Likewise with the manner of truck suspension: the swing-center truck is sometimes used in connection with flangeless drivers and sometimes not, while in other cases it is used with a wheel base all the drivers of which are flanged. It is a rule pretty well established, however, that with a swing-center truck the leading pair of drivers should be flanged. Cases are on record of mogul, consolidation, and 10-wheel locomotives with swing-center truck, and 8-wheel passenger engines with rigid-center truck, which were built and run in regular service with the leading drivers flangeless, but few or none of these engines are now in use. They are not regarded as safe on curves, and some prefer flanged front drivers with rigid-center pilot trucks also, for the reason that they hold to the rail better than bald drivers in case the pilot wheels become derailed. For security in running backwards the rear driver must, of course, be flanged.

As to the rate of widening gage for curvature exceeding the limit for which the wheel base is designed to run freely, that depends upon whether the widening is required for the driving wheel base, as in the case of locomotives with swing-center pilot truck and flanged drivers, within the limit of curvature on which the swing-center truck is effective; or whether the widening is required for the longer wheel base extending from the rear driver axle to the center of the pilot truck. In either case the theoretical widening would increase practically as the middle ordinate of a chord equal in length to the wheel base considered. In some cases the arrangement of the drivers might make it seem desirable to consider ordinates at points other than the middle of the chord, but the difference in any case is comparatively slight, and, for the sake of a general discussion, may be neglected. The middle ordinates of 12-ft., 14-ft., 15-ft. and 16-ft. chords, which may be taken to represent the lengths of driving-wheel base of various types of locomotives, increase at the rate of .04 in., .05 in., .056 in. and .07 in., respectively, per each degree of increase in curvature. The middle ordinates of 21-ft., 22-ft., 23-ft. and 24-ft. chords, which may be taken as representing the long base measurements for various types of locomotives, increase at the rate of 0.115 in., 0.128 in., 0.14 in., and 0.15 in., respectively, per each degree increase of curvature. It thus appears that for the driving base alone the rate of widening required varies, according to the length of the base, from $^1/_{25}$ to $^1/_{14}$ in. for each degree increase of curvature, while for the long base the rate varies from $^1/_9$ to $^3/_{20}$ in. per degree, according to length of base. In practice, however, a rate as large as that in the latter case is seldom applied. A few roads widen the gage at the rate of $\frac{1}{8}$ in. per degree above a certain limit at which widening is supposed to begin, but the rate used in the largest practice is $^1/_{16}$ in. per degree above the limit at which widening is supposed to begin, which is usually 4 to 6 deg. The maximum amount of widening with roads of moderate curvature is $\frac{1}{2}$ in. With roads of heavy curvature the maximum amount of widening is $\frac{3}{4}$ in. to 1 in.; but very few roads exceed 1 in.

The explanations necessary to reconcile practice with the foregoing theoretical requirements have already been indicated. On many roads the driver tires are set in to permit more play at the flanges than is provided for in the M. C. B. standards, $\frac{5}{8}$ in. play being common for front and rear pairs of drivers and $\frac{1}{2}$ in. for the middle or intermediate pairs of drivers. And then it should be noted that rails with side-sloping head, or a head with a long radius at the top corners, or with the top corner on the gage side considerably worn, conform more nearly to the shape of the wheel tread and flange than is the case with rails of American Society section, and therefore permit more lateral play of the flanges. In some cases, also, it is the practice to set the tires of the middle drivers of mogul and 10-wheel engines and of the intermediate drivers of consolidation and mastodon engines $\frac{1}{8}$ to $\frac{1}{4}$ in. closer between backs than on the front and rear drivers. So far as curves are concerned this is a better arrangement than to narrow the gage of the front and rear drivers, but it is hard on frog wings and on guard rails opposite frogs, and the practice should not be permitted. Any deviation from the M. C. B. standard wheel gage is bound to result in blows to guard rails and frog wings. This matter is more fully discussed under the subject of Guard Rails, § 59, Chap. VI. On roads of heavy curvature it is quite customary to leave more play between axle boxes and wheel hubs than is told of, since if the side play is not provided for in the shops the locomotive will soon make the play for itself, because on engines which bind in the curves the hub wear is very rapid. It is quite usual to leave side play of $\frac{5}{8}$ in. and even $\frac{7}{8}$ in. between wheel hub and journal box. Furthermore, the side wear of the outer rail is rapid on sharp curves, particularly if there is insufficient room for the wheel flanges, and of course such wear amounts to widening of the gage. All these discrepancies of what is considered standard practice assist in getting engines around curves in some cases where the widening of the gage seems clearly to be far too small. Investigation will usually disclose that the apparent disagreement between theory and practice in such cases is easily accounted for. Lastly, whether from the absence of these compensating features or their existence to an insufficient degree, there are instances where the inadequate widening of the gage is only too evident from the excessive crowding of the flanges, resulting in rapid flange and rail wear, spreading of the rails, and, in extreme cases the refusal of the engine wheels to follow the track. In cases where the engines bind extremely hard in the curves one may sometimes find long shavings of steel cut from the rails by the wheel flanges

Regarding the practice of widening gage on curves it may be said that no rules approaching uniformity are widely established. Some roads widen the gage on comparatively easy curves, while others adhere to the standard, even on very sharp curves. Out of 104 replies to inquiries on this point, addressed to railway officials by the American Railway Association, in 1897, 25 roads reported no increase of gage on curves. The other 79 roads reported numerous rules of increase, beginning at limiting degrees of curvature which vary widely. Table VIII is a summarized statement of these replies in condensed form.

It is remarkable that in reports and discussions on this subject, mention of the type of locomotive used, on the road reporting a particular practice respecting the widening of gage on curves is seldom made. Many persons who attempt to give reasons for widening the gage seem to think that all locomotives having long driving-wheel bases are equally severe on curves, quite ignoring the fact that the arrangement of the flangeless drivers and the method of truck suspension may make all the difference conceivable. Some study of the subject will convince any person that the type of locomotive wheel base has all to do with the question of widening the gage. Locomotives having rigid-center pilot trucks are perhaps easier on curves than those having the swing-center trucks, but they require more room on the track. On ordinary curvature the former require an increase in the gage and the latter do not, if the middle or intermediate drivers are flangeless.

Amongst railway mechanical officials the opinion is to some extent prevalent that the omission of the flanges on the intermediate drivers of a locomotive increases the resistance to traction, and the practice of flanging all the drivers of locomotives of all classes seems to be growing. Of course such practice compels the widening of the gage on curves of longer radius than would be necessary if the case was otherwise, and the claims in support of flanging all the drivers should therefore be zealously scrutinized by maintenance-of-way men. According to currently reported observation on the part of mechanical men the wear of the flanges on the front drivers of mogul, 10-wheel, consolidation and mastodon locomotives takes place more rapidly when the middle or intermediate drivers are flangeless than is the case when all the drivers are flanged. With roads of light curvature, where the ordinary side play in the boxes is sufficient to permit the intermediate drivers to flange with the outer rail, this may be true, and, of course, it might be supposed that flanges on the intermediate drivers take their share of the wear on straight track, but it is not easy to see how they can be of assistance to the front drivers on sharp curves.

This question of flanged drivers has twice been the subject of investigation and report by the American Railway Master Mechanics' Association.

Table VIII.—Practice of 79 Roads in Widening Gage on Curves.

Increase Commencing with	—Range of Increase—	Maximum Increase
1° on 18 roads	1°, increase 1-32-in. to ¼-in.	¼-in. on 5 roads.
2° " 5 "	2°, " 1-16-in. " ¼-in.	⅜-in. " 2 "
3° " 15 "	3°, " 1-16-in. " ⅜-in.	2-5-in. " 1 "
4° " 10 "	4°, " 1-16-in. " ½-in.	½-in. " 30 "
5° " 16 "	5°, " 1-16-in. " ½-in.	⅝-in. " 5 "
6° " 7 "	6°, " ⅛-in. " ½-in.	¾-in. " 24 "
8° " 3 "	7°, " 3-16-in. " 21-32-in.	9-16-in. " 2 "
9° " 1 "	8° and 9°, " ⅛-in. " ¾-in.	15-16-in. " 2 "
10° " 2 "	10° to 12°, " ⅛-in. " 1-in.	1-in. " 8 "
13° " 1 "	13°, " ⅛-in. " 1-in.	1 3-16-in. " 1 "
21° " 1 "	14° to 20°, " ¼-in. " 1-in.	
	20° " 30°, " ¼-in. " 1 3-16-in.	

The method of testing was to measure the drawbar pull in hauling the same locomotive around a curve, first with the usual arrangement of blind-tired drivers and then with all the drivers flanged. The main rods and valve rods were disconnected and a dynamometer car was coupled in between the locomotive under test and the one which did the pulling, to measure the tractive resistance. In the first report, submitted in 1899, the committee found no practical difference in the power required to pull a consolidation locomotive around the curve selected, with the different tire arrangements. The second report, however, presented in 1900, purported to be more decisive. This time the same committee reported to have found that it took less power to pull a locomotive (around the same curve on which the experiments of the previous year were conducted) when all drivers were flanged than when some of the drivers had blind tires. The conclusion of the report is that it is desirable to have flanged tires on all the drivers of mogul and consolidation engines and on 10-wheel engines which have swing-center trucks; furthermore, that the tires of mogul and 10-wheel engine drivers and of the second and third pairs of drivers of consolidation engines should be set 53¼ ins. back to back (⅛ in. less than M. C. B. standard), and the tires of front and rear drivers of consolidation engines 53⅛ ins. back to back. The report makes no reference to any requirements as to the gage of the track, neither is the proper relation of the wheel gage to the gage of the track on curves considered in any manner. Apparently the only aim considered was to save flange wear, whether or not at the expense of the track.

A review of the tests on which this report was based is important, because it shows such a variation in the conditions of the different tests that the conclusions of the committee appear groundless and misleading. The tests were conducted on a 14½-deg. curve on the main line of the Lehigh Valley R. R., on an ascending grade of 56 ft. per mile. The track was laid the same year with 100-lb rails, to a gage of 4 ft. 8¾ ins., on good ties with tie plates, and the elevation of the outer rail was 5 ins. The particular part of the curve on which the observations were taken was 476 ft. in length. The engines tested were a 10-wheeler and a consolidation just out of the shop, with a lateral motion of ⅛ in. between wheel hub and axle box. The gage of truck wheels and of driving wheel tires in all of the tests except one was 53¼ ins. between backs, which, considering the gage of the track, would give ¾ in. play at the flanges. Three series of tests were made with each engine, with a different tire arrangement each time, each series of tests comprising three runs at speeds intended to approximate ten, twenty and thirty miles per hour; that is to say, there were nine runs with each engine, or one run at each speed for each tire arrangement. The same two engines were used in all of the tests.

In the first test with the 10-wheeler it had a rigid-center truck and the front drivers were flangeless; in the second test it had a swing-center truck and the middle drivers were flangeless; in the third test it had a swing-center truck and all of the drivers were flanged. In the first test with the consolidation the intermediate or second and third pairs of drivers were flangeless; in the second test the second pair of drivers were flangeless and in the third test all of the drivers were flanged. In this last test with the consolidation the tires of the leading and trailing drivers were set 53⅛ ins. between backs of flanges, or ⅛ in. closer than the gage of the intermediate drivers. The results of the test in which all the drivers were flanged, in the case of both engines, show a smaller average drawbar pull than was registered in either of the tests on each engine with the other tire arrangements, but the variability of the conditions divest the entire series of tests of any meaning. The rigid-center truck in the first test with the 10-wheeler eliminates that test from consideration, and in the tests with the consolidation the gage of the front and rear drivers was not the same in all cases. But the irregularity which completely defeated the purpose of the experiments was the fact that the tests with both engines when all the drivers were flanged were conducted on a wet rail, in a light rain, whereas all the other tests were made in clear weather, on a dry rail. The effect of such a conspicuous disparity the committee assumed to dispel by sanding the rail before the test, but the efficacy of such an expedient is certainly conjectural. Moreover, the scheme of the tests was badly planned, in that only one run was made at each speed for each tire arrangement, and the speed recorder showed too much variation in the speeds actually made to admit of fair comparisons. For instance, the speeds made in the second run in each of the three tests with the 10-wheeler were 16.2, 22.95 and 24.5 miles per hour, respectively, and in the corresponding run in the three tests with the consolidation they were 18.6, 22.7 and 18.6 m. p. h., respectively, when they were supposed to approximate 20 m. p. h. The corresponding other runs in the tests with each locomotive were equally variable as to speed, as were also the averages of the three runs in each of the tests, the same for the 10-wheeler being 17.8, 21.2 and 22.2 m. p. h., respectively. It would have conduced better to the usefulness of the results had it been attempted to make all of the 18 runs of the series at the same speed. Lastly, some inconsistencies appear in the results figured from the dynamometer records and spring curve, which reflect badly upon the calculations.

The reason for criticising the work of this committee thus in detail is the fact that the conclusions of the report have been quite widely accepted as final, by both mechanical and maintenance-of-way men, when really the report, for the purpose intended, is of but little or no value. In any event, however, the resistance of the drivers to passing a curve when the engine is hauled loose, at the end of a train, as in the case of these experiments, may not be the same as that which obtains under service conditions, when the same engine is under the strain of hauling a train around the curve.

The effect of flanging all the wheels of such locomotives as are covered by the conclusions of this report reaches farther than the matter of widening gage on curves. In the case of a frog or guard rail on the outside of a curve, the channel or flangeway, which is supposed to be but ⅜ in. wider than the thickness of a wheel flange, is parallel to the curve, whereas the intermediate driver or drivers must run on the chord of the arc which terminates at the end drivers. Unless, in such cases, where the curvature is heavy, the channel of the frog or the flangeway of the guard rail is made to special order the backs of the flanges of the intermediate drivers will impinge heavily upon the wing of the frog or the guard rail—it is a "tight place" for an engine to "worm" itself through. The conclusions of the report as to the gage of driving-wheel tires are at variance with the M. C. B. standard wheel gage and therefore open to the criticism already referred to respecting blows to guard rails and frog wings. A supposedly better arrangement for the variation of flange play with the drivers is that which has been in vogue for many years on the Delaware, Lackawanna & Western R. R. On that road the driving-wheel tires are all set to the M. C. B. standard distance, 4 ft. 5⅜ ins. back to back, and increased lateral play for the front and rear drivers is provided by varying the thickness of the flanges. On mogul engines the play at the flanges of the front drivers is ¼ in., at the main driver flanges ⅝ in., and at the back driver flanges $\frac{1}{2}$ in. On consolidation engines the play at front and back driver flanges is $\frac{7}{8}$ in. and at second and third driver flanges $\frac{5}{8}$ in. The lateral motion between hubs and axle boxes is $^3/_{16}$ in. But this arrangement is hardly an improvement, from the track standpoint, because the thinned flange permits the back of the flange on the mating wheel to strike that much deeper into the guard and wing rails on that side.

The prevailing tendency is to widen the gage of curves too much or to widen it where the necessity for doing so does not exist. One of the objectionable features, or supposed evil effects, of widening the gage of curves is that it permits car trucks to slew more on the track and hence to run with greater obliquity of flange contact with the outer rail, resulting in excessive side wear to the rail and to wheel flanges, waste of tractive force and increased tendency for wheels with sharp flanges to climb the rail. Particularly is such the case with the forward truck of cars which are hard down on their side bearings. With the running gear in this condition the resistance of the truck to adjust itself to its natural position on the curve will cause it to run with the wheels on opposite corners crowding the rails with excessive pressure, and the wider the gage the greater is the slewing angle, as just stated. Then, after passing out of the curve the truck will continue to run cornerwise and cause the forward wheel in flange contact to grind against the rail. Trucks out of true also tend to run in the same manner, and the situation is all the worse for widening the gage. In numerous instances abnormal side wear to the outer rail of curves laid to widened gage has been observed to cease upon drawing in the rails to close gage, and the usual explanation is that on rails laid to close gage car trucks run in a position more nearly parallel with the track.

The effect which widening the gage has upon flange wear and train resistance, or the resistance of car trucks, does not appear to have been well investigated, experimentally. From all the indications which trend in that direction, however, it seems reasonable to raise the question whether it might not be more important to pay heed to the proper relation of the track gage to the car-wheel gage, as affected by curvature, than to seek to reduce flange wear and the resistance of locomotive drivers by some tire arrangement that compels a sacrifice in the way of increased car truck resistance by reason of an enforced widening of the track gage. The car wheels in an average train are many, whereas the locomotive wheels are comparatively few, and it is well worth the study to determine which demand the greater consideration on curves. As an illustration, it is probably true that engines with rigid-center trucks and a suitable arrangement of flangeless drivers, with sufficient room in the gage of the curve, are easier on the track than engines of the same type with swing-center trucks and any possible tire arrangement. Nevertheless the greater widening of the gage required for the engines with rigid-center trucks on the sharp curves may cause extra resistance from, and wear to, the car wheels which will more than offset any advantages with that arrangement for the truck.

From the trackman's point of view the moral effect of widening gage is questionable. It usually occurs that any departure from the general standard in this respect leads to a good deal of looseness; for where a curve is supposed to be spiked $\frac{1}{4}$ or $\frac{1}{2}$ in. wide, one is quite likely to find almost any variation up to $\frac{3}{4}$ in., and, if not, the rail will soon wear enough to make the gage excessive for the needs. These discrepancies lead to carelessness in gaging tangents, and the matter of close gage gradually ceases to be regarded cautiously for either tangents or curves. Therefore gage should not be widened unless it is absolutely necessary that it should be done. It is a very important question whether rolling stock should be built for the track or whether the track should be gaged to suit rolling stock built to arbitrary standards respecting curvature.

Sharp Curves and Curve Guard Rails.—For standard-gage main-track service curvature exceeding 4 deg. is considered sharp, 10 deg. is very sharp and 15 deg. (radius 383.1 ft.) is a limit at which the great majority of railway engineers will stop if the situation will permit. The sources of danger to train operation on curves are bad surface and alignment in the track, hard-swiveling trucks, sharply worn wheel flanges and unequally loaded or top-heavy cars. With one or more of these conditions present the chances of derailment increase with curvature and, in most instances, with speed also. On curves so sharp that danger of derailment from any of these defects is thought to be threatening it is quite commonly the practice to lay a continuous guard rail around the curve on the gage side of the inner rail. The most usual limit of curvature at which the need of guard rails is supposed to begin seems to be about 16 deg., although they are used to some extent on curves of less degree. Such a guard rail should be laid to bring the service side 4 ft. 6¾ ins. from the gage side of the outer rail, regardless of any widening of the gage or of the width of the flangeway between it and the running rail. A notable example of sharp curvature in main-line service is the curve around the abandoned "Mud Tunnel" on the Pacific division of the Canadian Pacific Ry., in the Kicking Horse pass, between Golden and Field, B. C. The radius of this curve is only 262 ft., which corresponds to curvature of 22 deg. The curve is 755 ft. in length and is guard-railed on the gage side of each running rail the whole distance. The purpose of the guard rail on the inner side is to prevent wheels from mounting the outer rail, and the purpose of the guard rail next the outer rail is to carry blind drivers. The running rails are laid broken joints, to a gage of 4 ft. 9¾ ins., and the guard rails break joints with the adjacent running rail. The flangeway between guard and running rail in each case is 2¾ ins. Both the running rails and the inner guard rail are backed by rail braces on every third tie, and on every third tie there is a piece of plank fitted between the two guard rails. The outer rail is not elevated, the omission of this feature being necessary to prevent the roof projections of passenger cars from "cornering," which would result if the car bodies were tilted.

Another notable example of sharp curvature on standard-gage main track is found with the Rossland branch of the Canadian Pacific Ry., from Trail to Rossland, B. C., originally known as the Columbia & Western Ry. In its length of 13.6 miles the road rises 2300 ft., and there are thirty 20-deg. curves having an aggregate length of 3 miles. The grade on tangents is 4 per cent and on curves it is compensated .04 per cent per degree. The rails are laid on Servis tie plates with three spikes in each, which hold the track to gage without using rail braces. The gage is widened one inch and there are no guard rails except at three trestles located on these sharp curves. The outer rail is elevated only 2 ins. Originally it was only 1 in., but after two years it was increased to prevent the track, which is filled in with light ballast, from getting out of line. Heavy consolidation and other locomotives of ordinary type have been operated on this line successfully. The average traffic has been four trains each way per day. Passenger trains make 12 miles an hour and freight trains 8 miles per hour over these curves. The Mexican Central Ry. has a 3-per cent mountain grade with curves varying from 15 to 24 deg., there being only one tangent in 30 miles, and that only a few hundred feet long. The gage of the track on the sharp curves is 4 ft. 9 ins. and the maximum elevation on curves is 3 ins. There are guard rails on all curves exceeding 17 deg. The rails are of 75-lb. section. Consolidation engines with 15-ft. driving wheel base, total wheel base 23 ft. 5 ins., all drivers flanged, the drivers carrying 80 tons, are operated on this line. The lateral play between wheel hub and driver box is $\frac{1}{4}$ in. for the front drivers, $\frac{1}{8}$ in. for the second and third pairs of drivers and $\frac{1}{2}$ in. for the rear drivers. The relatively small superelevation on the foregoing curves deserves notice, as it is on the side of safety of operation where guard rails are not used. Increase in elevation of the outer rail on sharp curves decreases the proportion of the load on the outer wheels and increases the tendency of those wheels to climb the rail when moving at slow speed.

The tires of blind drivers are usually $6\frac{1}{2}$ to 7 ins. wide, or $\frac{3}{4}$ in. to $1\frac{1}{2}$ ins. wider than the tires of flanged drivers. This extra width is to afford a margin of wheel bearing to allow for the range of lateral movement possible for such drivers relatively to the rails on curves. Nevertheless on heavy curves, particularly where the gage is widened excessively and the outer rail is badly flange worn, a blind driver will sometimes drop inside the outer rail and derail the locomotive. Of course the chances of such an accident are greatest with consolidation or mastodon locomotives whereon both pairs of intermediate drivers are flangeless or with mogul or 10-wheel locomotives having a long driver base with the middle pair of drivers flangeless. Under fairly supposable conditions a derailment of this kind can be accounted for. For example, consider a driving base of 16 ft., on a 15-deg. curve, laid with 80-lb. rails to a gage originally widened 1 in., and suppose the outer rail to be flange worn $\frac{3}{4}$ in. If the flangeless tire is $6\frac{1}{2}$ ins. wide and is set to run centrally with the rail on straight track then it is necessary to find a lateral movement of $3\frac{1}{4}$ ins. + $1\frac{1}{4}$ ins. (half width of rail head) — 1 in. (middle ordinate 16-ft. chord) — $\frac{3}{4}$ in. = $2\frac{3}{4}$ ins. for the rectangle of the driving base in order to account for the dropping of an intermediate blind driver. The widening of the gage gives a play of 1 in., the standard play of the flanges $\frac{3}{8}$ in. more, a set-in of the flanges of leading and trailing pairs of drivers $\frac{1}{4}$ in. more, wear of the flanges $\frac{1}{2}$ in. more, play at and wear to the hubs and axle boxes $\frac{1}{2}$ in. more, or altogether about $2\frac{5}{8}$ ins. The remaining $\frac{1}{8}$ in. the drivers will find at some place where the spikes are spread or at some angling joint. This estimate does not take into account the "personal equation" of trackmen in widening gage, already explained, or as much play as might be figured if a lighter rail with narrower head was used, but it serves to show what is liable to happen under conditions which sometimes exist; and it also shows what a large factor the widening of gage is in trouble of this kind. The difference in the length of the middle ordinate of a 16-ft. chord on the curve considered, and a side ordinate at a point corresponding to the position of one of the intermediate drivers of an eight-coupled set, is only $^1/_8$ in. As the tendency with engine drivers is to run to the outside of the curve as long as traction is maintained, the danger with blind drivers dropping from the rail is greatest when they slip, as then they lose their grip on the rail and slide toward the lower side of the curve.

The necessity for some provision against the dropping of blind drivers does not usually seem to be taken into consideration until after a few derailments have happened. Then, to avoid further trouble, a guard rail is laid inside the outer rail and another outside the inner rail to carry the flangeless drivers. Such guard rails are usually laid as close to the running rail as requirements, such as room for the spikes and proper width of flangeway, will permit. For splicing guard rails fish plates are more convenient than angle bars, and the nuts should be on the side of the guard rail which is not in service—that is, on the side farthest from the running rail, so as not to come in the flangeway.

In the present connection it is proper to point out that blind tires should not be set to a closer gage between backs than that of the flanged tires, and, in any contingency, never closer than 53 ins. If the backs of the blind tires are set closer than the distance between the backs of the flanged tires the false flanges of the blind tires when badly worn will drop into the flangeway at guard rails and frog wings and heavy blows to those parts will result. The increment of width to blind tires should be made to the outside, because there is where it is most needed. The liability for a blind driver to drop inside the outer rail is always greater than for its mate to drop outside the inner rail. This is because the liability of a flangeless driver to drop outside the inner rail is not increased by widening the gage; in fact the probability is decreased. The liability of derailment to blind drivers on the outside of the inner rail depends only upon the thickness of the flanges, the play at the hubs of the blind drivers and the width of the rail head; it is even independent of the spreading of the spikes, however badly. Consider, as a presumably bad case of this kind, an engine having a 16-ft. driver base, with flanges worn $\frac{1}{2}$ in. and with $\frac{3}{4}$ in. play at the hubs of the blind drivers, passing a curve laid with 60-lb. rails. Then before an intermediate driver with blind tires set even with the backs of the flanged tires can drop off the inner rail there must be a middle ordinate of $1\frac{3}{8}-\frac{1}{2}-\frac{3}{4}+2\frac{3}{8}$ ins., $= 2\frac{1}{2}$ ins., to a chord of 16 ft., which corresponds to a 37-deg. curve. Even in the extreme contingency that the outer rail had been flange worn $\frac{3}{4}$ in. and changed over, the blind driver would still be safe against dropping off up to curvature the middle ordinate of which to a 16-ft. chord is $1\frac{3}{4}$ ins., or 26 deg.

Rail Wear, Sharp Flanges and Derailment.—The causes of derailment on curved track have not been investigated as extensively as the importance of the subject would seem to warrant. It is currently accepted that sharply worn flanges and the forces acting upon car or locomotive wheels are the causes which contribute to derailment on curves, but just what the conditions are when they reach the danger point is not so widely understood. So far as car wheels are concerned the code of rules of the Master Car Builders' Association specify that a flange worn to a "flat vertical surface extending more than 1 in. from the tread, or a flange 1 in. thick or less," are defects which justify removal. A noteworthy treatment of the general subject of derailments is to be found in a paper by Mr. J. H. Wallace, engineer maintenance of way of the Southern Pacific Co., presented before the Pacific Coast Railway Club, in January, 1900. The theory by which he explains the derailment of a wheel on a curve is based upon the ratio of the vertical force, due to the weight of the wheel and its load, and the horizontal force acting upon the wheel, due to the reaction necessary to curve the engine or truck combined with centrifugal force arising from speed. To show cause for the lifting of the wheel when it becomes derailed, account is taken of the shape of the wheel flange, but the shape of the rail head is left out of consideration, the claim being that the conditions are not essentially changed on a flange-worn rail. The theory propounded by Mr. Wallace concerning the position which a wheel will take on the outer rail of a curve is that the wheel makes contact with the rail on that part of its running surface which is perpendicular to the direction of the resultant of the forces acting upon the wheel. On straight-line track the resultant is, of course, vertically downward, and the wheel runs upon its tread; while on curved track, if the speed be sufficiently great, the relative magnitude of the centrifugal force will cause the resultant force to assume a direction approaching the horizontal, and in that case the wheel will rise from the top of the rail and run upon the side of its flange, against the corner of the rail head. The condition which obtains when the wheel is on the point of being derailed is that the direction of the resultant force becomes perpendicular to the face of the flange on that line where the curve of the flange reverses. Beyond this line the curvature of the flange approaches nearer and nearer to a horizontal direction; or, in other words, the slope of the flange becomes more gradual, thus facilitating the climbing action of the wheel. On a new wheel the resultant is supposed to have this direction when the horizontal force becomes equal to 2.4 times the vertical force.

Respecting the claim that the chances of derailment are no greater when the outer rail is flange worn than when it is new, opinions differ. Some authorities on the subject claim to have observed that the flange-worn rail is usually in evidence wherever derailments take place on curves. Numerous experiences have been cited to show that with locomotives having pilot trucks of both the swing and rigid-center type and front drivers with both flanged and plain tires no difficulty was had until the rails on the curves became flange worn. In fact there is much evidence on both sides of the question. In one case numerous derailments have been observed on new rails, while in the other case practically all of a large number of derailments have been observed only on flange-worn rails. To get at the merits of the contention it seems proper to inquire respecting the nature and effect of the friction of contact between wheel and rail. With a new wheel on a rail worn to almost any shape commonly found in service the friction of the parts in contact is mainly rolling friction, the condition least conducive to derailment, but as the rail becomes flange worn the side and corner of the head are reduced to an outline approaching that of the average wheel flange and fillet, and a sharply worn flange, which usually slopes back on a straight bevel from the fillet, will, by the slewing of the truck, on sharp curves, make a surface contact with the rail in advance of the line of contact at the tread. The result is a grinding against the side of the rail head, due to contact at peripheries of unequal diameter, which, in connection with the side thrust of the horizontal force, must exert a considerable lifting effect upon the wheel which Mr. Wallace's theory does not take into account. There is therefore room to doubt whether this theory applies as strictly to worn wheels and rails as it does to new ones.

Mr. Wallace's paper treats of another set of conditions which should not be overlooked when contemplating the safety of wheels in passing around curves. Reference is made to the change in the ratio of the vertical and horizontal forces due to the fluctuation of the weight on the wheels. This fluctuation may arise through oscillation on rough track; through uneven loading of the car; through top-heavy loads, which may set the car to rolling, or which, at slow speed, may cause the car body to incline to the inside of the curve and relieve the outer wheels of some portion of their load. The fluctuation of loading is an important matter affecting the design of locomotives for safe running. If the forward truck of a locomotive has a rigid center the truck should sustain a larger share of the weight of the locomotive than otherwise, for under this condition it becomes the duty of the truck to compel the locomotive to follow the curve, and it is not safe to take chances on a too great proportion of the weight being momentarily reduced by a teetering motion of the locomotive on rough track or by the upward reaction of the connecting rods against the guides. If the truck is provided with a swing center, however, the conditions are essentially different, for then the guiding of the locomotive is performed by the forward driver, which is not so subject to violent fluctuations of the loading.

45. Curve Elevation.—The purpose of elevating the outside rail of curves is to overcome or lessen the unpleasant tendency of the car bodies to swing and tilt outward from centrifugal force, and also to lessen the wheel flange pressure against that rail. The commonly accepted idea that elevation or "superelevation" in the outer rail lessens the tendency of the wheels to climb the rail does not always hold true. The action of wheels relatively to the rails on elevated curves is in nowise different from what it is on curves level across. The flange pressure of wheels against the outer rail of curves may arise from two forces, namely, centrifugal force. due to speed, and the resistance of the wheel to being turned from a straight course, which is independent of the speed. With proper elevation for the speed the centrifugal force may be counteracted, but the lateral pressure due to the tendency of the wheels to run straight ahead is always present. It is therefore impossible, by any known arrangement, to prevent flange pressure of wheels against the outer rail of curves.

While speed higher than that for which the curve is elevated does increase the flange pressure against the outer rail it also increases the weight or vertical force acting down upon the wheel, and there are conditions under which the vertical force may increase relatively faster than the horizontal or centrifugal force. The less the elevation the greater is the weight thrown upon the outside wheels, at any speed, and the less the weight on the inside wheels—the very condition which conduces to the easier turning of the car truck or wheel base, to cause it to follow the curve or to make derailment less probable. A car loaded unevenly, with the excess of weight on the inside of the curve, will, at slow speed, climb the outside rail more readily if that rail be elevated than it will if the two rails be on the same level, because there is an undue proportion of the weight on the inside wheels and less weight to hold down the wheel flanges on the outside. The resistance of the inside wheels to lateral sliding may then overcome the action of the force which tends to constrain the flanges of the outer wheels to follow the rail. Danger from this source is greatest on sanded rails. The same action holds true of cars with top-heavy loads—at slow speed the car body leans heavily toward the inside of the curve and tends to lift the outer wheels from the rail. If the curve was level transversely such would not be the case.

Reference is intended mainly to tendencies, for they do not reach the danger point except at limits which would indicate extremely careless running. It is not an easy matter to determine in any case whether the greatest source of danger in running around curves which are level transversely, at very high speeds, lies in the liability of upsetting the car, in the spreading of the rails or in the tendency of the wheels to climb the outer rail. It is the habit of mathematicians who attack this problem to consider the vertical force on the outer rail as constant, at half of the load, which is very clearly not the case; and then figure the speed at which the wheel may be supposed to mount the rail or overturn it. The premises in an investigation of this kind are necessarily uncertain. The moving car should not be considered as a whole. For the purpose of the investigation it is in two parts—the trucks constituting one and the body and its load the other—and within limits these parts act independently of each other. The center of gravity of the car body and load changes, with the speed, relatively to both the trucks and the track. At slow speed it is shifted toward the inner rail and at high speed it is shifted toward the outer rail. The fact that locomotives and cars running at high speed on curves have been known to completely overturn without first being derailed to the ties shows that the outer wheels hold down to the rail pretty firmly when centrifugal force is acting strongly upon the car body. In fact the source of greatest danger to the derailment of the wheels by mounting the outer rail is rough surface in the track.

The main advantages to be gained, then, by elevating curves are comfort to passengers, in traveling at high speeds, and less pressure of the wheel flanges against the outer rail. But while such advantages are feasible and very desirable for trains of the better class, still, where the slow-speed trains are comparatively numerous there are evil effects arising such as call for a compromise between the elevations suitable to each class. If the slow-speed, heavy-traffic trains are comparatively few in number the curves should be elevated for the high-speed trains. As regards traction at slow speed, more force is required to haul a car around an elevated curve than around one which is level across, owing to increased curve resistance. As the elevation increases there is an undue proportion of the weight shifted to the inside wheels, owing to the fact that the gage of the wheels, which is the base upon which the car stands, is narrower than the width of the body of the car. Since it has been shown that it is the tendency of the inner wheels to outrun the outer ones which causes the truck to run askew to the track, it must be clear that increase of load on the inner wheels will increase the tendency of the truck to slew, which, as previously pointed out, increases the curve resistance. The effect which is sometimes thought to be due to decreased tractive power of locomotives on elevated curves is really caused by increased curve resistance in the cars.

A general formula for curve elevation has been worked out upon the mechanical principle that by elevating the outside rail the force of gravitation, which may be considered to act vertically on the center of gravity of the car as a whole, is resolved into two components—one acting perpendicularly to the track, and the other across the track parallel to the plane of its elevation, in opposition to the centrifugal force, so as to hold it in check. This formula is

$$e = \frac{g\ V^2}{32.166\ R}$$

where e is the elevation in outer rail, in feet; g the distance in feet between rails, center to center of heads; V the velocity in feet per second; R, the radius of the curve, in feet. Taking the velocity in miles per hour, the formula becomes

$$e = \frac{.06688 g V^2}{R}$$

But such a formula cannot be rigidly applied to widely varying speeds and to curves of all degrees in common use, because in actual service it is not practicable to vary the elevation as the square of the velocity. To do that would, for speeds ordinarily made on some curves, require an elevation so high that to slow down upon it would throw too much weight upon the inside wheels, and in all probability run some of the cars off the track; or to stop on such a curve might put a top-heavy car in danger of tipping over. For speed of 60 miles per hour this formula requires an elevation of 2½ ins. per degree, which is far in excess of rates of elevation used in general practice for that speed. To find rates of elevation in common use for speed of 60 m. p. h., by this formula, the speed used therein must be assumed at 38 or 40 m. p. h. In practice it cannot be expected to entirely overcome centrifugal force at high speed. The car body is attached to the truck so as to act on springs, and any great pressure of the wheel flange against the outside rail, due to centrifugal force at high speed, is taken care of by the downward force which the car body exerts on the wheel tread, thus preventing the flange from climbing the rail, and also to some extent holding the rail more securely against spreading. It is readily seen how a downward force is exerted on the outside wheels of a car by centrifugal force acting on the car body, which is held to the truck only by a pin at the middle, thus allowing the center of gravity of the body to shift relatively to that of the truck, as already pointed out.

A formula which gives an elevation most suitable for any curve, for the different classes of trains, is necessarily empirical, for it cannot be derived by a strict application of mechanical principles. As a matter of fact curve elevation in practice is determined by trial and not by mathematical calculation; it is a "cut and try" process, pure and simple. After satisfactory elevation for a series of curves has been found it is customary to express the practice in some simple rule applying to various degrees of curvature, but the rule in all such cases is nothing more nor less than a report of experimental work. For the sake of preserving a scientific aspect by making the above general formula for centrifugal force seem to agree with practice, some keep twisting it by the introduction of constants to suit the case, but in this there is a good deal of nonsense—practice can be expressed by a simpler formula. Usually the outer rail is elevated according to some recognized rule, or not quite enough to meet the supposed requirements, and then, if necessary, it is later adjusted until the cars seem to ride satisfactorily. On the Chicago, Milwaukee & St. Paul Ry. an instrument made on the principle of the spirit level (§ 195, Chap. XII.) is used on the cars to indicate whether they are properly canted for the speed of the train and to show the excess or deficiency in the superelevation of the outer rail. Experience has taught certain "rules of thumb" which are reliable enough for trial and far simpler to use than any formulas which involve terms expressing centrifugal force. For level track these rules are about as follows:

On electric railways, logging roads, or on any road where speed of 30 m. p. h. is not often attained, it is customary to elevate the outer rail ½ in. per degree of curve, up to a maximum of 4 ins.

For roads on which the freight traffic predominates, the passenger trains being local only, and speed of 45 m. p. h., while running, is not often exceeded, the usual rate of elevation is ¾ in. per degree, up to a maximum of 5 ins.

On roads which handle a mixed traffic, operating through or express trains, where speed exceeding 45 m. p. h. is commonly made, the most usual practice is to elevate 1 in. per degree, up to a maximum of 6 ins. Where the freight traffic may be disregarded a rate of 1¼ ins. per degree, up to a maximum of 6 ins., is quite frequently employed; rates of 1½ to 2 ins., and even 2½ ins., per degree, up to a maximum of 7 or 8 ins., are also in use, but not so frequently.

The rules for usual conditions on the New York Central & Hudson River R. R., whereon two of the four tracks are given to passenger traffic exclusively, are as follows: For main passenger tracks curves of less than 1 deg. are elevated at the rate of 2 ins. per degree, and curves of 1 deg. and over are elevated 1 in. per degree, plus 1½ ins.; main freight tracks, ¾ in. per degree; combination tracks 1 in. per degree. The maximum elevation is 6½ ins. On some other roads the rate of elevation for passenger train speed is 1 in. per degree, plus 1 in. This use of a constant additional to a uniform rate per degree gives a relatively high elevation for curves of the smaller degrees, which seems to be a principle extensively followed. In a larger number of instances, however, this result seems to be attained by the addition of a variable which decreases with the curvature; as, for instance, the rule may be to elevate 1 in. per degree, adding 1 in. for a 1-deg. curve, $\frac{7}{8}$ in. for a 2-deg. curve, $\frac{3}{4}$ in. for a 3-deg. curve, $\frac{5}{8}$ in. for a 4-deg. curve, and so on, the elevation for 1, 2, 3 and 4-deg. curves then being 2 ins., $2\frac{7}{8}$ ins., $3\frac{3}{4}$ ins. and $4\frac{5}{8}$ ins., respectively. The justification for this practice lies in the fact that the fastest speeds on curves are made on the curves of small degree, and the elevation for these curves, though relatively high for the curvature, is still not high enough to be objectionable to the freight trains. The Philadelphia & Reading Ry. makes use of a rule derived with the idea of maintaining the proper relation between curvature and speed, by which the superelevation is taken as the middle ordinate of a chord equal in length to the distance run by the express trains in one second. The maximum elevation is fixed at 8 ins.

The foregoing rules show that under usual conditions in general practice there is a compromise of the requirements of slow-speed freight trains and of the speed of fast passenger trains. It is important also to note several of the widely prevailing abnormal conditions under which general rules are not followed. On curves at stations where all trains stop there is no necessity for elevating the outer rail, and in usual practice it is elevated but little or not at all. On sharp curves in front of stations where some of the trains do not stop it is better to slacken speed than to place full elevation in the curve, because the inward tilting of the cars which stop on such a curve fully elevated is an inconvenience to passengers getting on or off, and when the platforms are slippery from rain or snow the footing is very insecure and passengers are in much danger of injury from falling. Also in the vicinity of stations, water tanks, unprotected grade crossings, draw bridges, etc., where stops are made or speed habitually reduced, the elevation of the curves is governed accordingly. In some cases where turnouts occur on curves the ordinary rules for elevation are not followed, the speed of trains being reduced at such places. At a crossing on curved track it is not practicable to elevate the curve at the crossing, and speed should be reduced.

Local conditions of grade also govern the matter of curve elevation to a considerable extent. Thus, for example, the elevation of curves on summits is usually less, and that of curves in the hollows usually more, than the customary elevation in vogue for curves of the same degree on level road. Where heavy grades occur on double track the conditions of speed in the two directions are so essentially different that the requirements of curve elevation are not the same for both tracks—the curves on the up-grade track are necessarily elevated for a much slower speed than are the curves on the down-grade track. Where long, heavy grades occur on single track it is manifestly impossible to elevate the curves satisfactorily for the ascending and descending trains, the usual speeds of which may differ as widely as 10 or 15 m. p. h. up hill and 50 or 60 m. p. h. down hill. This is only going a longer way around to say that it is impossible to elevate a curve satisfactorily for more than one speed. On single-track mountain roads it is customary to reduce both the rate of curve elevation and the maximum elevation. As an illustration of this practice, the standard rule of the Southern Pacific road for main line, except on mountain divisions having grades over 1.8 per cent, is to elevate the curves 1 in. per degree, up to a maximum of 6 ins. The rule for all mountain divisions having grades exceeding 1.8 per cent (as also for all branch lines) is to elevate the curves at the rate of $\frac{3}{4}$ in. per degree, up to a maximum of 5 ins. On other single-track roads where long, heavy grades prevail a rate of curve elevation as small as $\frac{1}{2}$ or $\frac{5}{8}$ in. per degree, with maximum elevation as low as 3 or 4 ins., is extensively used.

Curves in yards and sidings, on which speed is necessarily slow, are, as a rule, not elevated at all. Where a considerable speed is liable to be made on such tracks, however, a reduced rate of elevation is quite frequently applied, as, for instance, rates of $\frac{1}{8}$ in. per degree to half the rate for main line, stopping at 2 ins., which seems to be the maximum elevation most commonly applied to side-track.

Concerning maximum curve elevation for main tracks the majority of roads, including roads which run fast express trains, place the limit at 6 ins. An important matter which has a bearing upon this question is the limitation of speed in relation to curvature. There is a decided and widely prevailing belief on the part of maintenance-of-way engineers, well supported by experience, that at limits of curvature quite closely agreed upon the speed of the fast trains should be restricted. Coming to actual figures the preponderance of opinion among maintenance of way men agrees that speed as high as 60 m. p. h. should not be made on curves sharper than 4 deg. There are more who place the limit lower than 4 deg. than there are who place it higher, and but few, if any, place it above 6 deg. The basis of this opinion rests in the fact that the speed conditions of mixed traffic do not permit the ideal elevation of any but curves of small degree to be practiced. Assuming maximum elevation at 6, or even 8 ins., any of the customary rules for the fastest traffic cannot be followed beyond a limit of curvature which is comparatively low. It is also taken into consideration that the liability of cars to derailment from the binding of side bearings, from broken wheel flanges or other defects of the rolling stock increases with the speed and curvature, so that, as between the question of exceeding the most generally accepted maximum elevation, in deference to sustained speed, and that of reducing the speed, the latter course is the safer. A rule covering the case which seems to meet with approval is to establish a maximum elevation for speed of 60 m. p. h. on a 4-deg. curve, say 5 or 6 ins. The speed for 4-deg. curves is then limited to 60 m. p. h. and reduced 5 m. p. h. for each degree above 4 deg.; i. e., the speed for 6-deg. curves is limited to 50 m. p. h., for 8-deg. curves to 40 m. p. h., for 10-deg. curves to 30 m. p. h. and so on.

The consequence of insufficient elevation for the speed is unpleasant riding, due to the listing of the car body, but on sharp curves the tilting of the car floor to the level position, for moderate elevation and the highest speed, is not considered objectionable. On the other hand the ill effects from heavy slow-speed freight trains on sharp curves fully elevated for fast passenger traffic are widely observed. The objectionable effects commonly referred to are excessive wear to the inner rail, canting of the inner rail, abnormal cutting of the ties under the inner rail, the tendency of the track to constantly increase its elevation, owing to the disproportion of weight bearing upon the inner rail; displacement of the track in line and surface; tendency to derailment, particularly at bad joints, owing to the tilting of the car body toward the inside of the curve, which relieves the outer wheels of an undue share of the load; tendency of top-heavy cars to capsize; and increased train resistance. The tendency of the inner rail to cut the ties and cant under excessive elevation for slow-speed trains is quite marked, and conditions of this kind sometimes require the use of tie plates where they would not be needed if the case was otherwise. Thus, on the Philadelphia & Reading Ry., where the maximum elevation is 8 ins., the use of "heavy" tie plates is necessary to overcome the tendency of the inner rail to cant under the slow-speed trains, but according to official report tie plates are not found to be necessary under the outer rail.

Where the roadbed is not sloped for the elevation it is well, when putting up the track for the first time, to allow ½ in. for the greater settlement of the high side of the curve.

Running Out the Elevation.—Concerning the manner in which the elevation should be run out at the ends of simple curves there is some difference of opinion, but in the largest practice full elevation is given at the points of curve and the run-off is made wholly on tangent. It is the practice to some extent, however, to make half or two thirds of the run-off on tangent and the remainder on the curve, and good results are claimed. The philosophy of this practice is that in approaching a curve the car begins to tilt toward the inside as soon as it strikes the elevated rail and continues to do so until after it passes into the curve; and that this momentum in a lateral direction counteracts the centrifugal force which develops upon striking the curve, even if there be less than full elevation at the point where the curve begins; and that before the centrifugal force can so far overcome the tilting motion as to produce an effect upon the car body the car will have reached the point of full elevation, where the two forces are supposed to come to a balance.

The rate of running out the elevation is another point on which men of experience differ, but in the great majority of cases in practice the length of the run-off is 30 to 60 ft. per inch of elevation, the preference seeming to lie with the 50-ft. and 60-ft. rates. As time is an element in the tilting of the car body to the inclination of the track it seems reasonable that the length of the run-off should bear some relation to the speed, while, on the principle that the car should not be tilted for an unnecessary distance or period of time before the centrifugal force begins to act upon it, the run-off should be as short as may be without being abrupt. The condition which would seem to govern in this respect is the distance between the trucks of the passenger cars, as one truck should not be tilted so much in advance of the other that the car body cannot readily adjust itself to the different inclinations of the two. As the distance, center to center, of trucks on passenger coaches and sleepers is 40 to 55 ft. (on standard sleepers it is 54½ ft.) it would seem that a run-off as rapid as 40 ft. per inch of elevation, which would permit a difference of only 1 to 1½ ins. of elevation at the two points at which the car is supported, should not be objectionable. In my own experience I have found this rate satisfactory for fast trains. On the other hand the practice of running the elevation out a long distance on the tangent presents an unsightly appearance and subjects the cars to tilting for an unnecessary period of time. On a few roads the length of the run-off is the same for all curves, of whatever elevation. One of these roads is the Atchison, Topeka & Santa Fe Ry., in which case the length of run-off is fixed at 120 ft. On the New York Central & Hudson River R. R. the rate of run-off for elevation of 3 ins. and under is 120 ft. per inch, but for elevation exceeding 3 ins. the length of the run-off is fixed at 360 ft. It is the opinion of some careful observers of train movements on curves that on double track the run-off for the elevation at the entrance to a curve should be longer than at the leaving end.

Any arrangement for running out elevation on tangent is not entirely satisfactory. Straight track out of level on the approach to a curve is just as objectionable as anywhere else. To test the truth of this proposition let the reader run around a corner and attempt to lean inward before beginning to make the turn. The unbalanced state of the runner in that case is the condition of a car which careens before the trucks are skewed, upon entering a curve, and remains careened after the trucks have straightened, upon leaving the curve, as must happen where the run-off is made on tangent. This careening of the car before it enters the curve causes the wheel flanges to seek the lower rail and the journal bearings to take up their lateral play by sliding over in the same direction, the result being that the wheel flanges do not meet the outer rail until they are some distance into the curve, where they, at about the same time as the journal bearings, are liable to bring up suddenly with a shock. A more desirable arrangement is to have the wheel flanges crowding the outer rail when they enter the curve, and one way in which this is accomplished is to compound the curve at each end with a piece of easy curve, usually ½ deg., just long enough to make the run-off. In this way the wheels can leave the tangent on level track and strike the curve, that is the main part of the curve, at full elevation, the flanges steadily crowding the outer rail all the while the full elevation is being attained. This is the most satisfactory way of running out the elevation of a simple curve. Of course the curve is in principle compound, but for the reason that the compounding is done primarily for convenience in arranging the run-off of the elevation, rather than for advantages in respect of curvature, the arrangement is not usually classified with compound curves. As the arrangement does not effect a gradual change of curvature it does not come within the meaning of what is ordinarily understood as an easement curve. For convenience of designation it might be called a "run-off" curve.

While fairly good results are obtained by the foregoing method of running out the elevation there still exists the undesirable feature that the largest portion of the run-off has an elevation not suited to the curvature, being far too much. The complaint is that this unfavorable condition gives rise to a centripetal force tending to hold the body of the car inward until it reaches the main portion of the curve, when the unbalanced centripetal force is suddenly changed to one that is centrifugal, with obvious consequences. The ideal method is to begin the change of direction with an easy curve having no elevation and develop the curvature gradually, or by a uniform rate of increase, to the point of full elevation, thus permitting the run-off at any point to be elevated to suit the degree of curve or radius at that point. This requires that the curve shall begin with radius infinity, or very long, and that the length of radius shall decrease gradually until the full degree of curve is reached. Such requirement is met by easement or transition curves, which are treated further along. In fact the only method of running out curve elevation that is entirely satisfactory is in connection with the use of easement or spiral curves, by which it is feasible to elevate with the curvature and maintain tangents level transversely their whole length. Wherever fast speed assumes importance practice is rapidly changing in the direction of spiraling the ends of the curves.

For a more detailed treatment of all the foregoing features of curve elevation, based upon an investigation of the practice of a large number of roads, the reader is referred to a paper by the writer included in the committee report on "Track," presented before the American Railway Engineering and Maintenance of Way Association, at the annual meeting in 1901.

Method of Elevating with Reference to the Grade Line.—Regarding the question as to whether the elevation should be made by placing the inner rail at the normal grade for top of rail and raising the outer rail the necessary amount, or by placing the outer rail at grade and depressing the inner rail, or making half of it superelevation in the outer rail, and the other half depression in the inner rail, it may be said that, as far as the running of trains is concerned, it does not matter; but for other considerations the best practice is to place all the elevation in the outer rail, leaving the inner rail at grade. Where there is a ditch at the curve one can readily see how this method of elevating will allow the same effective depth of ditch with less excavation than with either of the other two methods; and this advantage is all the more important if the ditch be continuous beyond the curve, out along an adjoining tangent. The practice of placing the outer rail above grade and the inner rail below it renders the surfacing of old track near the points of curves less satisfactory than is the case where one rail is placed at grade; because where grade stakes are lost—as they usually are on old track—it might be somewhat difficult to place either rail at point of curve to its proper hight; but it is always an easy matter to run either rail in at grade, because one has for reference the general surface of the adjoining rails on the tangent. It therefore simplifies the track work to either elevate the outer rail or depress the inner rail the whole amount of the required elevation. The term "depression," as used in the present connection, refers only to the position of the inner rail with reference to the grade line and does not necessarily imply that the inner rail is brought to position by lowering or cutting down the ballast or roadbed. As curve elevation is arranged when the track is ballasted it is usually the case that this rail must be raised some distance, the same as the outer rail.

There are three ways of elevating curves on double track with reference to the grade line. The most common of these, known as the "saw-tooth" method, is to have corresponding rails of each track on the same level. By this method the inner rail of the outer track necessarily comes in a depression, and drain boxes across one of the tracks are required at intervals to prevent the collection of water around that rail when a thaw occurs or when rain falls upon frozen ballast. The "step" method is that whereby the outer rail of the inside track and the inner rail of the outside track are placed at the same level (usually at grade), the elevation of the tracks then being arranged by raising the outer rail of the outside track and depressing the inner rail of the inside track. By the "plane" method the tops of all the rails of both or all tracks are placed on the same plane, so that there is an unbroken slope across both or all tracks. This is the best arrangement for draining the ballast and the one most favorable for laying a crossover, where such is unavoidable on the curve. A crossover is impracticable on tracks elevated by the "saw-tooth" method and it is not satisfactory if laid on tracks elevated by the "step" method. The "step" arrangement permits drainage without cross drains and for double track it is perhaps the preferable one. The objection to the "plane" method is that it requires the raising of the grade of the outer track or tracks, which must then be run off at the ends of the curve. On three and four-track roads the change of the grade at the ends of the curves in the outer tracks, required by this method, is considerable. This is the method of elevation adopted on the double, three and four-track lines of the Pennsylvania R. R. The standard of the Baltimore & Ohio and New York Central & Hudson River roads is the "saw-tooth" method, and on the Philadelphia & Reading Ry. the "step" method is standard. The New

England Roadmasters' Association, at its convention in 1897, voted in favor of the "step" method.

46. Reverse Curves.—A reverse curve is one formed by two curves turning in opposite directions and meeting tangent to each other. Two curves turning in opposite directions but having a piece of tangent between them do not constitute a reverse curve, although they are sometimes erroneously called such. Reverse curves are undesirable, but must sometimes be located. Speed should be reduced at such curves, because at the instant a car is leaving one curve and entering the other, centrifugal forces are acting in opposite directions on its two ends at the same time.

Elevation cannot be put in at the P. R. C. satisfactorily, because it is a point of curve for both curves. At the point of reverse curve the track should be level transversely, and the elevation run in both ways at the ordinary rate. If there is a short piece of tangent between two curves turning in opposite directions, and the piece is not long enough to allow for running out all the elevation from both curves, the full elevation should not be put in at the P. C. of either; but from a point between the two, distant from each in proportion to the elevation of each curve, run in the elevation of each at the ordinary rate until the full elevation is reached somewhere on the curve. This flattens out, as it were, the ends of the two curves, but it is better practice than to run out the elevation too suddenly. A piece of tangent between curves of contrary flexure, however short, is a good thing, for the opposite centrifugal tendencies of the cars at the point of reversal of a reverse curve is hard on draft gear.

47. Compound Curves.—A compound curve is formed where two or more circular curves, having radii of different lengths and turning in the same direction, meet tangent to each or one another in succession. The points of tangency are known as points of compound curve (P. C. C.). At such points the curve of shorter radius is usually given its full elevation and the excess gradually run out over the curve of longer radius, at the usual rate. On some roads, however, the run-off due to the change in elevation is distributed half on each section of the curve. The rule of the Atchison, Topeka & Santa Fe Ry. for running out the elevation between two curves, on a tangent which is too short to provide the usual length of run-off for both, is to divide the tangent into two parts in proportion to the degree of the curves which it connects (the longer part being next the curve of greater degree) and then make 90 ft. of the tangent "at the dividing point" level. From this piece of level track the length of run-off in each direction is 120 ft., using so much of the curve as is necessary for the purpose.

48. Curve Monuments.—A valuable aid in maintaining curves to good alignment is the ability to find points on the center line when wanted. While an experienced trackman in lining curves by the eye can keep them *smooth,* no man can keep a long curve *uniform* without reference points. A portion of the curve may get out of line slightly, and in lining it some other part may be thrown so as to conform to the portion out of line, perchance, instead of throwing the portion which is out of line back to place. In this way, after some years, it will usually be found that the curve has departed from the original center stakes, to one side or the other, and, even if by but long and gentle "swings", still the curvature cannot be uniform; some portions will be too sharp, others will not be sharp enough. At no place in the curve is this departure so noticeable and troublesome as at the point of curve. The "heavy shock," so called, experienced or felt when entering or leaving a circular curve, is often due to a failure to keep the P. C. or P. T. where it should be, and the ends of the curve in proper alignment. Moreover, all foremen do not understand that a simple circular curve cannot be eased off at the end without introducing at the curve end of the eased portion a longer or shorter piece of greater degree than the original curve, unless the whole curve be thrown in. Hence, when the end of the curve gets out of line, some foremen will attempt to throw two or three rails near the end in such a manner as to run the curve farther out from the old P. C., with a view to easing it off. This practice almost always results in a "bad job" affair, and the consequence generally is that the curve is never again got into good alignment without a new setting of stakes.

At the two ends, at least, of every simple curve, some monument of durable material should be set to mark the points. The expense of such provision will in the end be less than the cost of sending surveyors occasionally to find the points. It is also a good plan to have monuments every 50 ft. around the curve. On single track the monuments at the ends of curves are sometimes set on the center line, but usually a standard distance outside, say 7 or 8 ft. from the center; on double track monuments should be midway between track centers. The monument is often so placed that its top is made the grade for either the top or the base of the rail—better the base, as then it is lower and more out of the way. Stone posts cut square, about 3 ft. long, are extensively used and answer well for curve monuments. A cross is usually cut on top, extending from the four corners, to mark the center; or a drilled hole filled with melted brass or lead is sometimes used. The standard curve monuments of the Pennsylvania Lines West are iron pins 2 ins. in diam. and 4 ft. long, and dressed stone posts 6 ins. square on top and 3 ft. long. The stone posts are always used in slag ballast.

Short pieces of rail are also extensively utilized for curve monuments, and, considering that such short pieces accumulate rapidly and can otherwise be used only for scrap, they may be cheaper than stone. To make a rail monument more secure against disturbance or against being pulled up, the bottom end may be split along the web and the two parts bent out to form a "T", or an old splice bar may be bent at a right angle and bolted to the bottom of the piece of rail. In roadbed which is subject to heaving the monument should be set in cinders extending below the frost line. If the monument is a piece of rail which is also used to mark the grade, it should be stood on a flat rock in the bottom of the hole when it is set. Stone monuments placed at points where the curvature changes are usually smoothly faced, so that a record of the station number and degree of curve can be cut thereon. Monuments at other points on the curve, as at points 50 ft. apart, answer fully as well if only roughly cut or perhaps not squared or cut at all, and on single track they should preferably be set along the inside of the curve, just outside the ends of the ties,—say about 5 ft. from the center of the track—a few inches lower than the bottoms of the ties, covered up in the ballast. Being set a known distance apart they may be easily located and quickly uncovered when wanted. Pieces of rail or large stones of any shape, buried up and permitted to settle before the reference point is marked, are good enough for this purpose.

Compound curves should by all means be monumented at the P. C. C.'s and for some distance each way therefrom, if not all the way around the curve, so that at all times reference to the centers may be available. Transition or spiral curves are usually marked at both ends; that is at the point of spiral (P. S.), or the point where the spiral joins the tangent, and at the point of curve (P. C.) or point where the spiral joins the circular curve. Spirals should also be monumented for points on center not farther apart than 30 ft. The only way to maintain such curves in proper alignment is to have permanently established references to points on the center line. Without these references the section foremen cannot keep the spiral to its place as well as they can a circular curve without permanent reference points, and a spiral curve badly out of line affords no easement, so far as the curvature is concerned.

49. Rail Braces.—Rail braces, where needed, can render good service. There is usually more need of rail braces just a few years after track has been laid than there is with older track, for the reason that for the first few years after track is built the ties decay more nearly all at the same time. When double spiking on the outside will not hold, rail braces or tie plates must be used. They need not be applied, however, until the track begins to show signs of trouble from spreading. About five braces to the 30-ft. rail, on the outside, will usually be found sufficient for curves as sharp as 4 or 5 deg. On curves of 8 or 10 deg. and sharper, where braces are needed, it is quite commonly the practice to use them on every other tie, or eight or nine braces to the 30-ft. rail. These statements apply only in a general way, for the number of braces needed in any case necessarily depends a good deal upon the hardness of the ties. On hardwood ties braces are not usually needed unless the curvature is very sharp or the traffic heavy, while curves laid with softwood ties may need bracing for even moderate conditions of curvature and traffic.

Although the inside rail of curves is subject to spreading it is seldom, if ever, necessary to brace it. The most frequent cause of the spreading of this rail is that the gage of the curve is too narrow for the locomotives running over it. Undoubtedly some have noticed the inside rail spread slightly and then no farther, even though no attention was paid to bringing it back to proper place. The explanation of the phenomenon is simply that the locomotives made room for themselves. The inside rail may also spread slightly under the friction of the lateral sliding of the wheels, but not to do harm. In my own experience I have never seen an instance, where the gage was properly adjusted, that double spiking of the spread rails on the inner side of a curve failed to hold. A strange doctrine which has frequently been advanced to account for the spreading of the inner rail of curves is that the flange pressure against the outer rail pulls the ties through on their beds, the inner rail in some unaccountable manner holding fast and causing the spikes to be crowded out of place. When it is considered that each pair of wheels is tied together by the axle and that the rails are tied together by the ties, it would seem that any lateral action of the outer wheel should pull the inner wheel over with it and that any movement of the tie resulting from such action should bring the inner rail along. To any question, then, as to whether the lateral pressure of the wheels against the outer rail will pull the ties from under the inner rail, one may at least venture the proverbial argument of the old colored gentleman, that "such a case must be very rare." Those who think it necessary to brace both rails usually place the braces in pairs, opposite to each other, on the same ties.

It should further be said that the use of braces on the inner rail cannot prevent that rail from canting if the conditions are favorable to such action. A rail brace is designed to oppose lateral pressure, but not the vertical pressure which causes the rail to tilt and cut into the tie at the outer edge of the base. Where this tilting occurs the weight bearing upon the brace through the rail head tips the brace out of its adapted position, as shown in Fig. 54, loosening the spikes and readjusting the bearing of the brace against the rail. It is also to be noted that on rails which cut into the ties without canting the effectiveness of the braces, if used, is diminished in much the same manner. Where such are the conditions the costlier practice of using tie plates is a more satisfactory means of preventing the spreading of the rails. Combination devices embodying the features of both the tie plate and the rail brace are used to some extent, but experience with tie plates alone seems to demonstrate that they are able to take care of canting rails as well as to prevent the rails from cutting the ties; and where the rails cut the ties badly some means of protection should be afforded every tie.

It is better economy to use a few rail braces than to have to be pulling spikes, plugging the holes and redriving the spikes, as such weakens the tie and shortens its life. Frequently, however, double spiking every tie on the outside of the outer rail of the curve will hold it without rail braces, and it is a much cheaper method. As already stated, double spiking is always more satisfactory if done when the track is laid. Formerly, rail braces were pretty generally made of cast iron, thick and heavy, but late years cast steel and pressed steel braces of lighter weight have become standard. A pressed steel or cast steel brace is better than one of cast iron, since it is not broken by misdirected spike-hammer blows, and, being thinner, gives a spike more leverage or purchase with which to hold. It should be made to fit accurately the rail section with which it is used,

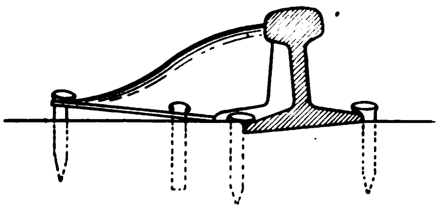


Fig. 54.

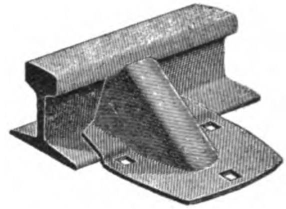


Fig. 55.

and it should extend well up against the rail head, but not higher than $\frac{7}{8}$ in. below the top of the rail for which it is designed, so as to allow $\frac{1}{2}$ in. for wear of rail and $\frac{3}{8}$ in. for guttered tires.

The principal patterns of rail braces now in use are shown by Figs. 55 to 60 inclusive. Figure 55 is the Alkins forged steel brace. The flange of the brace and the top fish into the rail like a splice bar, the wide bearing on the rail base being intended to hold the rail firmly to the tie, so as to prevent up and down motion in the same, and also to permit the first two spike holes to come close to the rail base, where their holding-down power is greatest. Figure 56 is the Elliot brace, of similar design in some respects, but having in addition a top shoulder, to fit against the head of the rail, and claws projecting from the base like those of a Goldie tie plate, to enter the tie and afford lateral resistance to assist the spikes. Figures 59 and 60 show two designs of the Weir die-formed steel braces. The flange of this style of brace is cut off at the edge of the rail base and abuts squarely against the same. The difference in the designs is that the one shown as Fig. 59 has open spike slots in the edge of the flange, while that shown as Fig. 60 has enclosed spike holes through the flange and affords more bearing surface upon the tie. In another design the side spike holes are enclosed, as in Fig. 60, and the place for the rear spike is an open slot in the edge of the flange, as in Fig. 59. Each of the designs is made with metal of either of two thicknesses—$\frac{1}{4}$ in. or $^5/_{16}$ in., as desired, the thicker brace being intended for rails of heavy section. The foregoing pressed steel braces of the box form are supposed to fit over the spike already in the tie when the brace is applied, but unless this spike happens to be at or near the center of the tie face (which is not likely to be the case) it comes in the way of the brace and it must be pulled and redriven

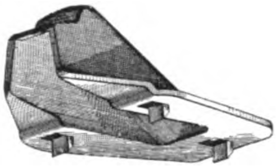


Fig. 56.

Fig. 57.

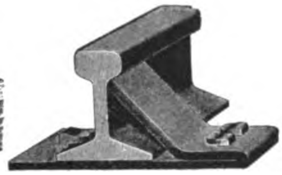


Fig. 58.

before the brace can be set. On the Southern Pacific road there is in service a forked rail brace made to fit around one spike set against the base of the rail. It is made of cast iron and is about 7 ins. wide.

Figure 57 shows the Ajax cast steel brace, designed to set over the spike already in the tie, as well as over the rail base, and fit against the web of the rail and side of the rail head. An excellent feature of this brace is that it can be set without interfering with the spike already in the tie in whatever position. For use on sharp curves this brace is sometimes ordered made with a $\frac{3}{8}$-in. offset to overlap the ends of tie plates. Figure 58 shows the Edwards combination rail brace and tie plate.

As the joint is the weakest place in the rail, it is spread the most easily; consequently there ought to be a rail brace designed to fit against the splice bar. In event such a design was gotten up it would be well to have about 25 per cent of the whole number ordered to fit the splice bars, as, if the joints could be made secure, the braces could in many cases be omitted from the quarters. The practical difficulty in designing a joint brace to fit against the web or vertical portion of the splice bar is the presence of the bolt heads or nuts and the creeping of the rails. In view of such conditions I would recommend a brace bearing only against the horizontal leg of the splice bar. Such a brace might consist of a flat plate punched for the spikes and flanged on the service edge to take the bearing of the splice bar. To provide against undercutting, through abrasion of the tie, this flange should project downward $\frac{1}{2}$ or $\frac{3}{4}$ in. into the tie.

Rails spread worst in winter, when the ground is frozen and the ties are held rigidly to their work. This is usually the busiest season of the

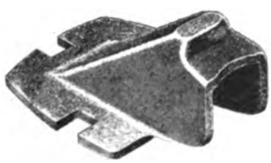


Fig. 59.

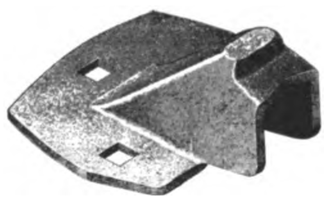


Fig. 60.

year for regaging and bracing spread rails on curves, and when the demand for braces is urgent it is frequently the case that some form of device must be improvised. Broken splice bars always come handy for this service, and, sometimes, even pieces of plank are used. In fact, a piece of 2-in. plank about 12 ins. long and, say, 4 to 6 ins. wide, makes a fair brace for temporary service. It should be set against the web of the rail and secured by at least two spikes against the end of it, the hook of the spike head being driven to sink into the block. Then to prevent the block from swinging out of place a spike should be driven through it. Good rail braces may be made of old fish plates by bending up one end so that it will fit under the rail head. There will then be left three holes for spikes, and a fourth spike can be driven at the end, if needed. In some cases the end of the fish plate is bent over against the web of the rail, something after the style of the Ajax brace. In setting rail braces all the old spike holes under the braces should be plugged.

In extremely bad cases, on very sharp curves, switch rods spaced a few feet apart are employed to prevent spreading of the rails. A bridle brace used at one time on the Stampede switchback of the Northern Pacific Ry. consisted of a bar with the ends bent around to clasp the flanges of the two rails on the outside only. They were easier to apply than switch rods and served the purpose just as well.

50. Transition Curves.—Easement, elastic, transition, parabolic, spiral, and tapering curves, as they are variously called, all signify the same thing—the gradual easing off or flattening out of circular curves at the ends, so as to make a gradual transition, as it were, from the tangent to the circular curve. It has already been explained that the transition curve enables a satisfactory arrangement of the run-off of curve elevation, since it affords a means by which the elevation can everywhere be adjusted to the desired relation with the curvature. A word further may be said by way of emphasis. After entering a curve a car has two movements relatively to the tangent behind: one progressively, that is, moving in the same direction as the tangent; and another normal or sidewise to the tangent. Now the car wheels begin their movement normal to the tangent the instant they strike the curve, and if at just this instant the car body could be tilted inward sufficiently by rail elevation, at just this instant its movement normal to the tangent would receive its initial impulse from elevation, and not from side pressure from the wheels; because in tilting inward from elevation in the track the car body, as a whole, actually moves inward as well. But such an arrangement in elevation cannot be had on simple circular curves, for the elevation must be developed gradually, in some considerable distance. With the spiral, however, the movement normal to the tangent can begin more gradually, because the track can be given its elevation so that at every point such elevation is adapted to the degree of the curve at that point; and hence at every instant leading up to the main part of the curve the car body is being gradually tilted inward by rail elevation at the same time that it is being accelerated in the normal direction—instead of being started by sudden pressure from the wheels, after the body has been already tilted while running over an elevated approach on the tangent.

The value of easement or transition curves is greatest where sustained high speed is practicable. Elevation for simple circular curves can be run in quite satisfactorily for good speed, and it is only where extraordinary results are desired that the greater expense and care necessary to maintain the easement curve can be justified. The most practical or satisfactory application of the easement curve is then not so much to curves so sharp that in any event speed must be reduced in running around them, but to those curves of comparatively smaller degree where, with the aid of the transition curve, the slackening of speed may be avoided; and while by using the transition curve a slightly higher speed on curves of, say, above 6 or 8 deg., might be had with a feeling of greater comfort or security, perhaps, still its use on curves less than 6 or 8 deg. must no doubt be the more justifiable practice. Not necessarily, then, are transition curves best suited to roads of heaviest curvature. Furthermore, it will usually be found that the surroundings which determine the location of a sharp curve will allow of but little room for easements. In any case the easement should be no longer than to give sufficient distance in which to run out the elevation. Any available room beyond this had better be used in reducing the curvature of the central or circular portion of the curve.

51. The Cubic Parabola.—A transition curve having a variable radius which gradually decreases in length from infinity, at the point where it meets the tangent, to a length equal to the radius of the circular curve, at the point where it meets it, is a desirable one to use, but it is also desirable that such curve should have an equation so simple that it readily adapts itself to easy calculations. A curve whose equation is of the form $y^n = A\,x$ is recommended, because of its simplicity and facility of application.

If some point be taken as an origin and rectangular axes of co-ordinates be drawn through this point, and points on the curve be plotted with reference to these two axes, the rate at which the curve departs from one of the axes, depends upon the power n, this power being given to the function which determines the position of any point on the curve with reference to the other axis. That is to say, the curve departs from one axis as many times as fast as it does from the other axis, by the n th power of its proportional distance from the other axis, at any point. But the scale to which the curve is drawn depends upon the value given to A; and by the scale is meant the relative length of the radius of the curve at any

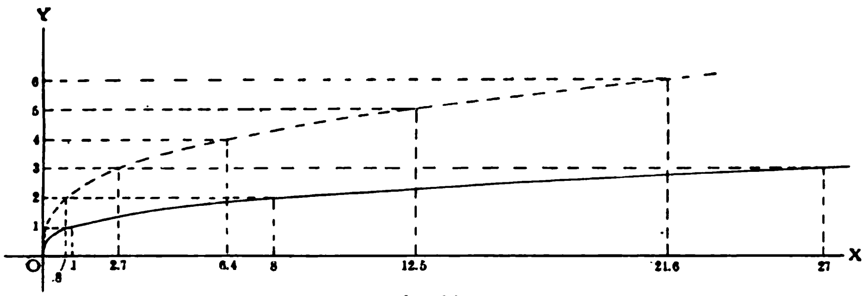


Fig. 61.

point. Thus the value of n determines the form of the curve, and the value given to A the size of it, as will be explained presently.

Now regarding the value of n, simplicity of calculation requires that it be an integral number and as small as can be used. To make it 1 would, of course, give the equation of a straight line; and to make it 2 would give a parabola, the maximum curvature of which comes at its vertex or origin, which is not a curve suitable for our use. The exponent 3 gives the *cubic parabola,* whose radius of curvature at the origin is of infinite length, being what is desired, and so to save complication no higher exponent need be used. To show to best advantage how this curve can be used we will plot it and point out its main features. In order to simplify matters suppose that at first we let $A=1$; then the equation of the curve becomes $y^3=x$. Let through the point O, Fig. 61, two axes of co-ordinates, $O\ X$ and $O\ Y$, be drawn at right angles to each other. Then all distances measured in a direction perpendicular to $O\ X$ will be denoted by y and distances measured in a direction perpendicular to $O\ Y$ will be x distances. Substituting different values for y we get: $y=0$, $x=0$; $y=1$, $x=1$; $y=2$, $x=8$; $y=3$, $x=27$; ....$y=10$, $x=1000$.

It is seen that the curve starts from O and after making a sharp bend rapidly flattens out; and that its distance from OY at any point, is, compared with its distance from OX, as the cube of its distance from OX. Thus the curve, while leaving OX gradually, leaves OY very rapidly, and the curve soon flattens out, so that it approximates to a straight line parallel to OX; or in other words it becomes a curve with radius rapidly approaching infinity. But let us consider the curve near the origin for values of y less than 1.

Let $y = .9$ then $x = .729$
$y = .8$........$x = .512$
$y = .7$........$x = .343$
$y = .6$........$x = .216$
$y = .5$........$x = .125$
$y = .4$........$x = .064$
$y = .3$........$x = .027$
$y = .2$........$x = .008$
$y = .1$........$x = .001$
$y = .01$.......$x = .000001$

While the curve makes a sharp bend between $y=0$ and $y=1$, it is seen that as y gets smaller in value the corresponding value of x gets smaller in proportion to the cube of the decrease of y. Hence, as the curve is followed toward the origin it approximates to a straight line parallel to OY, and at the origin it must be a straight line or curve of infinite radius.

Let this curve be cut into two parts or branches, call them for convenience, making the cut at the point of sharpest curvature. This point is at $y=0.3865$, $x=0.0577$ (see Fig. 62), at which point the radius of curvature is, of course, a minimum, and equal to 0.56744, or 1.46815 times

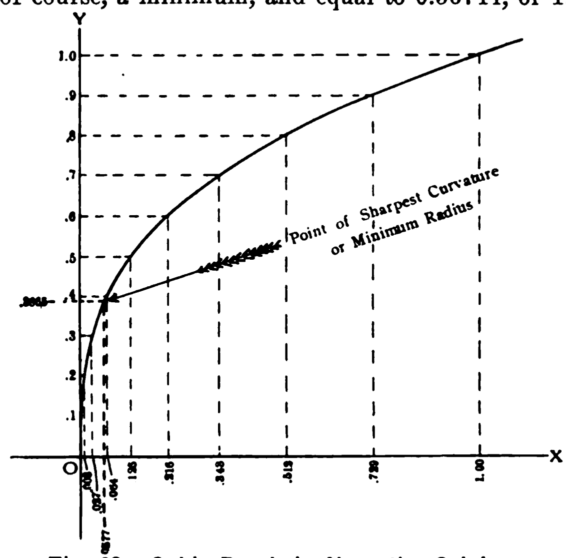


Fig. 62.—Cubic Parabola Near the Origin.

the value of y. By following the curve to the right from this point we pass from curvature of very short radius to curvature which rapidly approaches infinite radius, but reaches it only at infinite distance—that is, never reaches it; while if we go to the left, or toward the origin, we pass along curvature rapidly approaching infinite radius, which does actually reach infinite radius at a definite distance, that is, at the origin. So while the two parts of the curve under consideration vary in curvature according to the same law, each at the same rate relatively to itself, and while each branch passes through all degrees of curvature down as low as the minimum radius named, there is this difference: comparatively, the flattened portion in the right-hand branch is infinitely longer than the more curved portion of the same branch; while with the left-hand branch the flattened portion is, compared with the more curved portion of itself, infinitely times as short. It is, then, this latter branch or part of the curve which is the better suited for an easement curve, because the portion of the curve having radius very great, or infinitely long, is needed only for a short distance at leaving the tangent. The portion referred to is that between the origin and the point marked $y=0.3865$, $x=0.0577$, and is therefore only a small portion of the curve, as shown. This portion of the parabola can furnish a transition curve for any circular arc whose radius of curvature is not shorter than the minimum radius of curvature of the parabola. In practice, however, only part of this small portion considered is generally used, so that, to apply it to curves on the ground, its scale must be enormously enlarged. As stated previously, this is done by assigning a greater value to A.

Suppose, for the sake of discussion, that A be taken at 10. The values of x corresponding to values of y, taken in succession, will then be for $y= {}^1/_{10}$, $\frac{1}{2}$, 1, 2, 3, 4, 5: $x={}^1/_{10000}$, ${}^1/_{80}$, ${}^1/_{10}$, ${}^8/_{10}$, ${}^{27}/_{10}$, ${}^{64}/_{10}$, ${}^{125}/_{10}$, and when plotted gives the broken curve in Fig. 61, with minimum radius 1.7944, at $y=1.2222$. It might at first appear that the broken curve is of different form from the other. Such, however, is not the case, as both are identically of the same form, but one is simply drawn to a larger scale than the other. It is found that the scale of the plotted curve increases as the square root of A, the minimum radius always being equal to $0.56744\sqrt{A}$, and coming at $y=0.38650\sqrt{A}$; the minimum radius also equals 1.46815 times this value of y. So by assigning a suitable value to A in the equation we may start off with a curve leaving the tangent at radius infinity, and, at any desired distance out on the curve, obtain curvature which will coincide with that of any circular curve with which we wish to join it at that point.

Now it is found that for 0.45 of the distance between the origin and the point of minimum radius (p. m. r.) the cubic parabola follows almost precisely a curve the radius of which varies inversely as the distance measured along the Y axis (which, within the same limits, would be practically a measurement along the curve); and that up to 0.65 of the distance to the p. m. r. its departure from such a curve is inappreciable. For the remainder of the distance up to the p. m. r. the rate of change of curvature becomes less—that is, the radius of curve gets slightly longer than what would be its length did it decrease in exact proportion to the increase of distance along the axis. Coming down to fine points, then, this much may be said of the cubic parabola: If used within .45 of its length from origin to p. m. r., it gives a curve whose radius decreases almost precisely as length of curve increases, and up to .65 of its length to p. m. r. it does not depart appreciably from such curve; it is, therefore, to all intents and purposes, the ideal, within the latter limit.

Although beyond the .65 point the change of relation between the length of curve and radius does not to an appreciable extent render the curve less desirable for an easement curve, and although it does not usually happen that so much of the curve is needed in practice, still an important fact should here be noted. The formulas given further along for running out the curve, although very exact up to the .65 point, cannot be applied to the whole length, and cannot be depended upon much farther than this point. The effect of this discrepancy is, of course, that in order to use the full length of the cubic parabola to the p. m. r. more complicated formulas than those given must be used; and, furthermore, to get reliable results from the formulas given, the length of the easement curve used should not exceed 0.38 of the radius of the circular curve; which, as applying to circular curves above 11 deg., might make an undesirably short transition curve.

It now comes to settling upon a value for A, to suit any case in practice. At any point on the curve up to the .45 point the product of the radius at that point by the distance of the point from the origin (that is, the y distance) is almost precisely constant and is equal to $\frac{1}{6}$ A, for any value of A whatever; and between the .45 point and the .65 point this product is practically constant and always very approximately $\frac{1}{6}$ A. This relation holding true for any point, permits the use of a particular point, so that up to the latter limit, then, A for any particular curve may be considered to be the product of three quantities; viz., R, y_e and 6; and the equation becomes $y^3=6Ry_ex$,* R being the radius of the circular curve and y_e being the length of the easement curve, measured along the axis or tangent. As R and y_e are each constant for any chosen case, their product is then a constant, and it is usual to express the equation in the form $y^3=6Cx$, C representing the product of the radius of the circular curve (which is to be eased off) by the length of the easement curve desired. The formation of an equation for an easement curve in any given case becomes, then, a simple matter, and approximate formulas for laying it down by

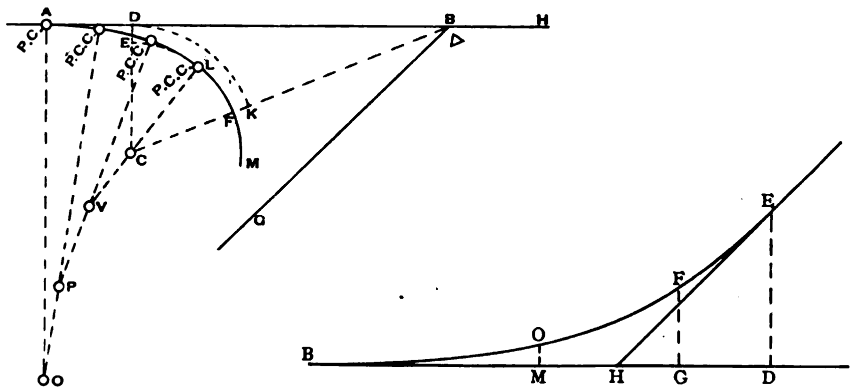


Fig. 65.—Tapering Curve. **Fig. 63.**

co-ordinates from the tangent considered as one of the axes, are equally simple.

Laying out the cubic parabola by tape-line measurements is simple work and it may be quite accurately done. Suppose (Fig. 63) it is desired to lay off a curve to the left of the line BD to some point opposite D. The distance BD is then the y_e of the formula. Suppose that at some point opposite D it is desired to develop a curvature of radius R. We then have the equation $y^3=6Cx=6Ry_ex$; or $x=\dfrac{y^3}{6Ry_e}$. The point E opposite D will then be distant

$$DE=x_e=\frac{(y_e)^3}{6Ry_e}=\frac{(BD)^3}{6R(BD)}=\frac{(BD)^2}{6R}$$

Any other point on the curve, as F, opposite G, will then be distant from BD, $GF=x_f=\dfrac{(y_f)^3}{6Ry_e}=\dfrac{(BG)^3}{6R(BD)}$. Or it may be found by proportion, thus:

$$GF:ED=(BG)^3:\ (BD)^3;\ \text{therefore}\ GF=ED\frac{(BG)^3}{(BD)^3}.$$

---

*The general expression is, of course, $y^3=6\ R_y y x$. As we are dealing with a parabola which joins a circular curve, R_e and R are equivalent and the equation, which otherwise would be expressed $y^3=6\ R_e\ y_e\ x$, is perhaps most convenient in the above form.

If $BM=\frac{1}{2}BD$ then $OM=ED\frac{(BD)^3\div 8}{(BD)^3}=\frac{ED}{8}$; and so any point on the curve between B and E may be found by computing direct from the formula; that is, by substituting in the place of y the distance from B to the foot of the perpendicular dropped from the point on the curve to the line BD; or its distance from BD will be such portion of ED as the cube of the distance from B to the foot of its perpendicular is to the cube of BD.

Having the curve laid out to E, it may be desirable to get its direction at that point; that is the direction of the tangent to the curve at that point, from which to lay off a circular curve by deflection angles, perhaps. From the calculus, the tangent of the angle which the direction of a curve makes with the tangent (BD) at any point $=\frac{dy}{dx}$. In this case it would be $\frac{dx}{dy},=\frac{3y^2}{6C}=\frac{(y_e)^2}{2C}=\frac{(BD)^2}{2R(BD)}=\frac{BD}{2R}$; that is, the tangent of the angle $EHD=\frac{BD}{2R}$, and the angle $HED=90$ deg. minus the angle whose tang. is $\frac{BD}{2R}$. Setting up at E, then, sighting the instrument on D, and turning off toward H the angle HED, puts the line of sight on tangent to the curve at E. But the point H may be determined by direct measurement.

Tang. $EHD=\frac{(y_e)^2}{2C}=\frac{(BD)^2}{2C}=\frac{ED}{HD}=\frac{(y_e)^3\div 6C}{HD}=\frac{(BD)^3\div 6C}{HD}$. Therefore $HD=\frac{2C}{(BD)^2}\times\frac{(BD)^3}{6C}=\frac{BD}{3}$. Measuring off HD, back from $D,=\frac{1}{3}BD$, gives the point H as a backsight to get on tangent at E.

Suppose it is desired to join two tangents by a circular curve having this parabolic curve at each of its ends. Let, in Fig 64, JK be one of the two tangents. Locate, at first on paper (or make calculations for whatever circular curve is desired for the main part of the curve) the point M, this being the tangent point of such curve. Decide what length (BD) is desired for the easement curve, and measure it off along JK equally each side of M, so that $BM=\frac{1}{2}BD$. The distance (DE) to the point where the parabola joins the circular curve will be, as before, $(BD)^2\div 6R$, where $R=$ the radius of the circular curve. M being midway between B and D, the distance (MO) to the parabola will be $\frac{1}{8}$ ED. Run through $M'R$ the tangent $M'K'$, RD being equal to $MM'=2MO$. Run in the circular curve $M'N'$ between the two new tangents. This curve can be met at E by a para-

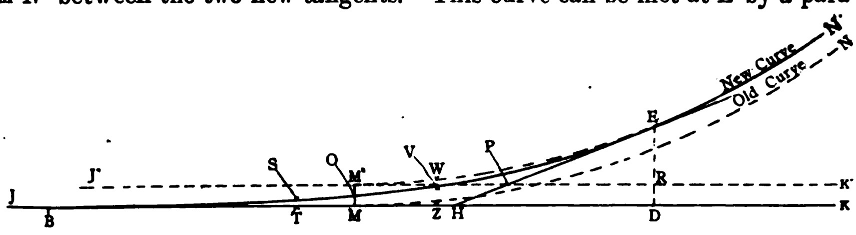


Fig. 64.

bolic transition curve which passes through B and O: for, from similarity of triangles, $PR=\frac{3}{4}HD$, because $RD=MM'=2MO=2\times\frac{1}{8}ED=\frac{1}{4}ED$; and $ER=\frac{3}{4}ED$. Therefore $PR=\frac{3}{4}HD=\frac{3}{4}\times\frac{1}{3}BD=\frac{1}{4}BD=\frac{1}{2}MD=\frac{1}{2}M'R$; and (very approximately) $M'P=PE$, as two tangents drawn from a point to a circular curve properly should be. This proves that, within the accuracy to which we are working, the tangent line $M'P$, from which the circular curve was run, is properly offset a distance $MM'=2MO$ from the tangent JK, from which line the parabola is run. Other points on the parabola between B and E may be located as described for Fig. 63. For instance, a point S will be from JK a distance $ST=x_s=\dfrac{(y_s)^3}{(y_e)^3}x_e=\dfrac{(BT)^3}{(BD)^3}ED$

Should any point, V, which it is desired to locate, be inaccessible to a measurement from JK, it may be located from the circular curve $M'N'$ by a measurement $WV=x_e\dfrac{(y_e-y_v)^3}{(y_e)^3}=ED\dfrac{(BD-BZ)^3}{(BD)^3}$; or it may be used as a check upon the other method. The distance of the point V from the old circular curve MN would, of course, be the difference between MM' and WV.

The parabola at the other end of the curve is laid out in the same way. To put a parabola on the end of an old curve, the old curve is first thrown in a distance $MM'=\frac{1}{4}$ of the distance calculated for ED according to the formula; the old curve is then relocated. Of course, the circular curve can be run from E, and need not be located back as far as M' except as a check.

The necessary formulas are now, for convenience, grouped together:

(1) $y^3=Ax=6Cx$; or $x=\dfrac{y^3}{A}=\dfrac{y^3}{6C}$

(2) $C=Ry_e$, or radius of circular curve $\times$ BD.

(3) $BM=MD=\frac{1}{2}BD$.

(4) $ED=x_e=\dfrac{(y_e)^3}{6C}=\dfrac{(BD)^3}{6C}=\dfrac{(BD)^3}{6R(BD)}=\dfrac{(BD)^2}{6R}$

(5) $MM'=2MO=\frac{1}{4}ED=\frac{1}{3}ER=\frac{1}{8}$ tangential offset of circular curve in a distance$=\frac{1}{2}$ the length of the easement curve.

(6) $x=\dfrac{y^3}{(y_e)^3}\times x_e=\dfrac{y^3}{(BD)^3}\times$ED.

(7) $WV=x_e\dfrac{(y_e-y_v)^3}{(y_e)^3}=ED\dfrac{(BD-BZ)^3}{(BD)^3}$

(8) $HD=\frac{1}{3}BD=\frac{2}{3}MD$.

(9) Tang. $EHD=\dfrac{y^2}{2C}=\dfrac{(y_e)^2}{2C}=\dfrac{(BD)^2}{2R(BD)}=\dfrac{BD}{2R}$

(10) Min. radius$=0.56744\sqrt{A}=1.46815\times y$ at p.m.r.

(11) y at p. m. r.$=0.38650\sqrt{A}$.

(12) R_y (Radius at any point y) $=\dfrac{y^3}{6yx}=\dfrac{y^2}{6x}=\dfrac{(y_e)^3}{6yx_e}=R\dfrac{y_e}{y}$

It now remains to show the application of these formulas to a practical example. Suppose it is desired to ease off a 6 deg. curve which has

5 ins. of elevation. As a precaution, the maximum length of useful curve to which the formulas will apply with exactness is $.38 \times R$ of 6 deg.$=.38 \times 955.4=363$ ft.; but as 200 ft. is sufficient length in which to run cut 5 ins. of elevation, we are far within the limit of accuracy. y_e is then equal to 200 ft., and our equation becomes $y^3=Ax=6Ry_ex=6\times 955.4\times 200\times x=1{,}146{,}480x$; or $x=\dfrac{y^3}{1{,}146{,}480}$. Simply to show another check, we find that the minimum radius of this parabola$=.56744\sqrt{A}=.56744\sqrt{1{,}146{,}480}=607.6$; which comes at $y=.38650\sqrt{A}=413.8$. We thus use less than half the available curve, and hence the application of the formulas to this curve is practically precision.

The distance x_e or ED will be $\dfrac{(y_e)^3}{6C}=\dfrac{200^3}{1{,}146{,}480}=6.98$ ft; and the offset MM' of the circular curve from the tangent$=\dfrac{6.98}{4}=1.745$ ft. Computing independently of the formula the departure of the circular curve from the tangent BD, after being set over 1.745 ft., is found to be 6.98 ft. at 100 ft. from M. This measurement agrees exactly with that for the point E at which the parabola should meet the circular curve, and thus shows that within the limits stated the reliability of the formula cannot be questioned. From (5) it is also apparent that ED is equal to $^4/_3$ of the tangential offset of the circular curve at a distance from the P. C. equal to half the length of the easement curve.

For circular curves sharper than 11 deg. a parabolic curve as long as 200 ft. cannot be accurately computed by these formulas, the limit of accuracy being restricted to a length of about $.38R$, as before stated. Formulas might be given which would accurately apply to the cubic parabola throughout its full length to the p. m. r.; but inasmuch as, for the most part easement curves are used with circular curves of less than 11 deg., it is considered that within this limit formulas so simple and accurate as the foregoing are more desirable to use than those necessarily more complicated. The formulas for computing deflection angles for laying out the cubic parabola with the instrument are not as simple, and it is therefore more usually the case that the curve is laid out by offset measurements from the tangent, as above worked out.

52. Tapering Curves.—Another method of easing curves that is largely in practice is the use of a series of compound curves of gradually changing curvature, the chords of which are equal and comparatively short, usually from 30 to 50 ft. The engineering departments of some roads have arranged tables of deflection angles for the use of their surveyors, so that these compound curves can be run out by the ordinary method of deflection angles, at one setting of the instrument at the P. C., instead of setting up anew at each P. C. C. located. A number of curves varying at different rates from 30 min. per 30 ft. (or whatever chord length), up to perhaps 2 deg. 30 min. per 30 ft., are used in different instances. For instance, in easing off a 2-deg. curve: beginning at P. C., it might be run out by starting with 30 ft. of a 30-min. curve, followed by 1-deg. and $1\frac{1}{2}$-deg. curves successively, each of 30-ft. chords, after which the 2° curve would be run in. A 15° curve might be eased off by five compound curves varying by 2° 30′ successively, until the full 15° is reached. Tables changing by 30 min., 1°, 1° 30′, 2° and 2° 30′ per chord length would apply to almost any curve in a manner to suit different men's ideas of the proper rate of easement. Formulas for length of tangent, and whatever modifications of simple circular curve formulas are necessary for properly locating the curves, are simple and easily worked out. These curves are usually called "tapering" curves. Although, in the process of running them out, the points established are points of compound curvature, the track need not be lined as so many compound curves but can be made to vary in curvature gradually by simply using the P. C. C.'s as points of a gradually varying curve, instead of points of distinct change of curvature. In this form, if the chords be short, the curve resembles closely the cubic parabola, and the elevation can be put in more satisfactorily, perhaps, since the full curvature is in this way attained by a gradually varying rate instead of by stages, as it were.

In Fig. 65 (not drawn to scale) is shown a circular curve, *LM*, eased off by three curves of different radii. Considering the case a general one, a number of formulas applicable to any curve, with any number of compoundings, will be derived. Let *A B* and *B G* be two tangents. Then the angle *H B G* will be the intersection or Δ angle, and it is required to know what measurements are necessary for laying out between these tangents a circular curve with tapering ends and how these measurements are derived. If *C* be the center of the main or middle portion of the curve, then a simple curve drawn between the two tangents about this center would be *D K*, it being, for the present purpose, necessary to show only half of it. The angle *D C B* is $\frac{1}{2}\Delta$, and the tangent distance *D B* is (*C D* or *C K*) $\times$ tang $\frac{1}{2}\Delta$. Suppose, however, that the curve *L M*, the center of which is *C*, is the main or middle portion and is eased off by any number of compounded circular curves having equal chord lengths. The tangent distance of the compound curve is *A B*, which for convenience we will divide into two portions, *A D* and *D B*. Let the distance *A D* be called "t"; the distance *C D*, "*S*"; and the distance *E D*=*F K*, "*s*." *O P*, *P V* and *V C* are the differences of the successive radii. *A D*=*t*, is then equal to the sum of the products of *O P*, *P V*, etc. by the sines of the angles which these lines, *O P*, *P V*, etc., respectively, make with the line *O A*, the radius of the first curve. In other words the distance *t*, for any central or main curve which may be used, is found by adding together the products of the successive differences of the radii of the curves leading up to the central curve, by the corresponding sines of the total curvature at the end of each of these successive curves. In like manner the distance *C D*,=*S*, for any central curve, may be found by subtracting from *O A* (the radius of the first curve) the sum of the products of the successive differences of radii by the corresponding cosines of the angles of total curvature at the ends of the successive curves.

The distance *ED*,=*s*, is equal to *S* minus the radius of the main curve =*S*—*R*.

The distance from the middle of the main curve to the intersection

$$\text{point}=FB=(S\times\text{ex. sec. }\tfrac{1}{2}\Delta)+s=\frac{S}{\text{Cos.}\frac{1}{2}\Delta}\text{ minus radius of main curve}$$

$$=\frac{S}{\text{Cos.}\frac{1}{2}\Delta}-R$$

The distance from P. C. to intersection point=$AB=DB+t=S\times$ tang. $\frac{1}{2}\Delta+t$.

The central angle of each portion of the compound curve is found by the solution of an isosceles triangle, two sides of which are equal to the radius of the curve; and whatever chord length is taken forms the third side.

The deflection angles from the tangent *AB* to each P. C. C., or from tangent at any one of the P. C. C.'s to any other P. C. C., are found by solving triangles wherein two sides and the included angle will be found given in each instance.

Table IX gives to the nearest half minute the deflection angles from the P. C., or from any P. C. C., to any point of change of curvature, for any central curve from 2 to 10 deg. The portions of the compound curve change 1 deg. each 40 ft. The distances *"S," "t,"* and *"s"* are given, also the total curvature to any point, and the long chord distance from the P. C. to the P. C. C. of the main curve. There is also included a list of ordinates for laying off the points of the curve by linear measurement alone.

In running out the curves by transit it is best, after fixing the P. C., to establish the P. C. C. of the main curve, using the tabular long chord distance and deflection angle or a direct measurement by the ordinate distances given. In this way a check is had on the work of the successive

Table IX.—Tapering Curves.

TAPERING CURVE CHANGING 1 DEGREE PER 40 FEET.

Transit at	Deflections to									
	P. C. 1°	P. C. 2°	P. C. 3°	P. C. 4°	P. C. 5°	P. C. 6°	P. C. 7°	P. C. 8°	P. C. 9°	P. C. 10°
P. C. 1°	0—00	0—12	0—30	0—56	1—30	2—12	3—02	4—00	5—06	6—19½
P. C. 2°	0—12	0—00	0—24	0—54	1—32	2—18	3—12	4—14	5—24	6—41½
P. C. 3°	0—42	0—24	0—00	0—36	1—18	2—06	3—06	4—12	5—26	6—48
P. C. 4°	1—28	1—06	0—36	0—00	0—48	1—42	2—44	3—54	5—12	6—36
P. C. 5°	2—30	2—04	1—30	0—48	0—00	1—00	2—06	3—20	4—42	6—12
P. C. 6°	3—48	3—18	2—40	1—54	1—10	0—00	1—12	2—30	3—56	5—30
P. C. 7°	5—22	4—48	4—06	3—16	2—18	1—12	0—40	1—24	2—54	4—32
P. C. 8°	7—12	6—34	5—48	4—54	3—58	2—42	1—24	0—00	1—36	3—18
P. C. 9°	9—18	8—36	7—46	6—48	5—42	4—28	3—04	1—36	0—00	1—48
P. C. 10°	11—40	10—54	9—50½	8—57½	7—47½	6—20½	5—03½	3—30	1—48	0—00

FOR TABLE IX

Degree of Main Curve.	Radius.	"S" (CD, Fig. 65)	"t" (AD, Fig. 65)	Total Curvature in Tapering Curve at each End of Main Curve.	"s" = "S" Less Radius of Main Curve. (E D, Fig. 65)	Long Chord from P. C. 1° to P. C. of Main Curve.	Ordinates.		
							Point.	Measured from P. C. 1° along the Tangent.	Measured Perpendicularly to the Tangent.
2°	2864.93	2865.01	20.00	0°—24′	0.08	40.000	P. C. 2°	40.000	0.140
3°	1910.08	1910.26	40.00	1°—12′	0.28	79.998	P. C. 3°	79.996	0.698
4°	1432.69	1433.39	59.99	2°—24′	0.70	119.992	P. C. 4°	119.976	1.955
5°	1146.28	1147.68	79.97	4°—00′	1.40	159.969	P. C. 5°	159.914	4.187
6°	955.37	957.81	99.92	6°—00′	2.44	199.909	P. C. 6°	199.762	7.674
7°	819.02	822.93	119.83	8°—24′	3.91	239.784	P. C. 7°	239.448	12.687
8°	716.78	722.63	139.69	11°—12′	5.85	279.545	P. C. 8°	278.865	19.494
9°	637.28	645.63	159.45	14°—23½′	8.35	319.133	P. C. 9°	317.871	28.358
10°	573.69	585.15	179.09	17°—59½′	11.46	358.463	P. C. 10°	356.285	39.509

deflections and short chord measurements. Should the main curve be of such degree that it comes between those given in the table—say a 5° 30′ curve—run in the tapering curve to P. C. C. 5°, putting in this point by the method just described. Then run in 20 ft. more of a 5° curve to P. C. C. 5°30′. In any case, for the last compounding of the tapering curve, take a length of chord which would divide the tabular chord in the same ratio as does the main curve divide up the angular distance between the two adjacent tabular curves. For instance, if the main curve were 5° 20′, use a chord ⅓ the tabular length, or 13⅓ ft.; for a 5° 45′ curve use a chord ¾ the tabular length, or 30 ft. Then correct the values of *S* and *t* as follows: multiply respectively the sine and cosine values of the total curvature up to the main curve, by the difference of radii of main curve and the last branch of the compound curve; add the sine product to *t* and subtract the cosine product from *S*, such values of *t* and *S* being taken from the table for the last branch of the compound curve.

Mr. Wm. Hood, chief engineer of the Southern Pacific road, many years ago worked out formulas and a series of tables applying to tapering curves, which are used on that road. His list includes tables for the following curves: one changing 30 min. each 30 ft., applicable to curves up to 10 deg.; one changing 1 deg. each 30 ft., applicable to curves up to 10 deg.; one changing 2 deg. 30 min. each 30 ft., applicable to curves up to 20 deg.; one changing 2 deg. 30 min. each 15 ft., applicable to curves up to 20 deg.; and one changing 15 min. each 30 ft., applicable to curves up to 5 deg.

The Torrey Easement Curve.—A similar system of transition curves is also in use on the Michigan Central R. R., where it was introduced by the late Mr. Augustus Torrey, chief engineer. Transitions from tangent to curve or from lighter curve to sharper curve are made by curves of regularly increasing degree, constructed upon a series of chords of equal length and compounded at the end of each chord. That end of an equal chord which joins an equal chord of less curvature is designated as the "small end" and that which joins an equal chord of greater curvature, the "large end." His list includes ten curves of the following tabulated description:

Length of equal Chords.	Variation per Chord.	Applicable to Curves up to
100 ft.	1 deg.	6 deg.
100 "	30 min.	4 "
50 "	1 deg.	12 "
50 "	30 min.	6 "
50 "	15 "	3 "
25 "	2 deg.	20 "
25 "	1 deg. 30 min.	15 "
25 "	1 "	12 "
25 "	30 min.	6 "
25 "	15 "	3 "

The data contained in the tables applying to these curves comprise the following linear and angular measurements: offset from the tangent through the small end of any chord to the large end of any chord; projection upon the tangent through the small end of any chord, of the line joining that point of tangency with the large end of any chord; prolongation to the tangent through the small end of any chord, of the radius drawn through the large end of any chord; length of long chord joining the small end of any chord with the large end of any chord; angle between the tangent through the small end of any chord and the tangent through the large end of any chord; distance on the tangent through the small end of any chord, from that point of tangency to an intersection with the radius prolonged through the large end of any chord; deflection angle from the tangent through the small end of any chord, from that point of tangency to the large end of any chord, and vice versa from the tangent through the large end of any chord, from that point of tangency to the small end of any chord. There are, in addition, tables giving data showing changes in line which follow upon the use of the various transitions given in the above mentioned ten tables. Problems involving the calculations for tangent lengths, central curve, easement of simple curve already built and easement of transition from one curve to a lesser one in the same direction are taken up and formulas deduced therefor. These problems are treated in a manner somewhat different from the foregoing treatment of tapering curves, since the formulas derived have reference to the intersection points on the two tangents to the curve, of the radii produced through the ends of the central or circular portion of the curve, instead of the points of intersection (D, Fig. 65) of radii drawn from the center of the circular portion of the curve perpendicularly to the two tangents. The solution of these problems, together with the tables referred to, and diagrams illustrating their use, have been embodied in a neat book of pocket size entitled "Switch Layouts and Curve Easements." The book, also, as the name implies, includes the solution of a number of switch problems.

53. Searles' Spiral.—The "Searles Spiral" is a multiform compound curve, the same in principle as the tapering curves just described, but susceptible of a much wider range of application and a much finer adjustment. A single spiral for any curve consists in chords of equal length subtending arcs of circles varying in degree by an amount which is practically a common difference (equal to the degree of curvature of the first arc), up to the degree of the main or central portion of the curve. The list includes different spirals with chords varying in length by 1 foot, all the way from 10 to 50 feet,—that length of chord to be chosen which for any curve seems to best suit the requirements. The rate of variation in curvature between any two adjacent arcs is always the same for any curve, notwithstanding that for different spirals the chord lengths are not the same. The real difference, then, between any two spirals is not in form but in the room taken up by them, or in the relative scale on which they are laid out. Its points as laid down form, for all practical purposes, the locus of a cubic parabola, the essential difference between the two not amounting to anything.

"The Railroad Spiral," a book of pocket size, contains a table of deflection angles for a curve of 20 points or less, and other tables giving deflections for a setting of the instrument at any point of the twenty; the central angle of the spiral, up to any point, is also given. The variation in curvature between any two adjacent chords being practically the same, the deflection angles remain the same for similar points in all spirals of any chord length, providing all the chords are made of equal length. The location of these spirals with the transit is thus reduced to the simplicity of running out simple circular curves. There are also tables corresponding to all chords varying, by 1 ft., between 10 ft. and 50 ft. These tables give the degree of curve for the arc subtended by any chord, in any spiral not longer than 400 ft., thus enabling a spiral suitable for any curve to be picked out of the tables. The choice of a spiral is had by choosing one such that the last chord of the spiral, and one more, subtends an arc equal in curvature to the main curve, or very nearly so. There is generally a large number answering the requirements, so that, by choosing from tables of different chord lengths, a spiral of almost any desired length, also, may be found. These tables further contain values of ordinates for points on the spiral, so that they may be laid off by tape-line measurements from assumed axes.

In my estimation "The Railroad Spiral" is the most easily adapted and the most practical printed matter to be had on transition curves, and it is published in a form convenient for immediate application to the uses of the field. In form the "spiral" is, for railroad use, just as good as any of the curves thought to be nearer the ideal but more complicated to calculate and apply. So far as practical results are concerned there is no sensible difference between any of the curves mentioned in this chapter. but there are considerable differences in methods of application, and the fact that with this curve the same deflection angles are always used, for any spiral, very much simplifies the field work and makes it undoubtedly the easiest to lay out. An investigation by the track committee of the American Railway Engineering and Maintenance of Way Association, in 1901, covering 83 of the principal railroads of the country, showed that 71 of those roads were using some form of transition curve. The form of tran-

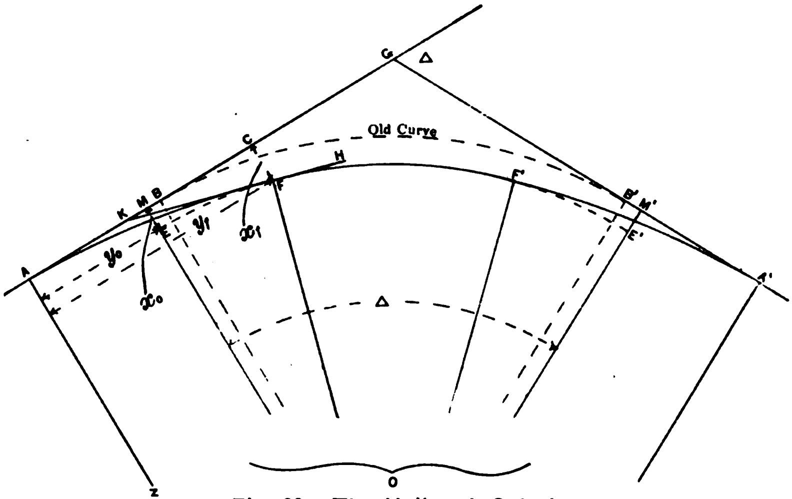


Fig. 66.—The Holbrook Spiral.

sition found to be in most extensive use was the Searles spiral, with the Holbrook spiral next in order of preference, these two being mentioned more frequently than all other forms of transition curves combined.

54. The Holbrook Spiral.—The theoretically true easement curve is the Holbrook spiral, worked out by Mr. Elliot Holbrook and first published in 1880. (At that time Mr. Holbrook was an engineer with the Pennsylvania Lines West. In 1900 he became chief engineer of the Kansas City Southern Ry.). As it leaves the tangent the radius decreases, or degree of curve increases, with the distance; that is, the degree of curve at any point is directly proportional to its distance measured along the spiral from the P. S. or point of spiral. Supposing R to be the radius of curvature at any point of the spiral, and L the distance of the point from the tangent point or P. S., measured along the spiral, then the definition of the Holbrook spiral is expressed by $RL=A$, where A represents some constant quantity. To illustrate this, suppose it is desired to use a spiral whose degree of curvature, beginning at the P. S., increases at the rate of 1 min. per foot or 1 deg. per 60 ft.; then, that the equation remain true it must apply to any point on the spiral which one may choose to take. If it be taken at the first foot, R would be the radius of a 1-min.curve,which is 343,774.68 ft., and $L=1$. Then $A=RL=343{,}774.68$; and it is the same for any other point, because R decreases just in proportion as L increases. Hence to find the radius at any point, distant L from the P. S., we use the formula $R=\dfrac{343{,}774.68}{L}$. This is for a spiral increasing 1 min. per foot; but if it increased at any other rate, A would have some different value, which could be found (nearly enough) by dividing 343,774.68 by the rate of change of curvature in minutes per foot. To find the length of spiral required to reach a circular curve of any certain degree, divide the degree of curve in minutes by the rate of change in minutes per foot—a very simple calculation.

Without taking up their demonstration, formulas for solving the simple problem of running in a spiral at each end of a simple circular curve, the intersection angle or Δ being given, will here be presented.

Referring to Fig, 66, let AG and GA' be tangents.

Δ =intersection angle.

BB'=simple circular curve.

B=P. C.; B'=P. T.

AF and $A'F'$=spirals.

FF'=circular arc in new position.

Δ_1=angle which tangent to spiral at any point $(x\ y)$ makes with the tangent line GKA; Δ_1 at $F=GKH=\Delta_t$. It is also the central angle of the spiral at any point.

D=deflection from any chosen point y_1 on tangent to any point (x, y) on spiral.

D'=deflection from a point on tangent GA, 200 ft. from A, to any point (x, y) on spiral.

$MOM'=\Delta$.

E and E' are points where the circular curve in new position becomes parallel to tangents GA and GA'.

Let GA be the axis of Y and AZ the axis of X, taking A for the origin; x and y will then be the co-ordinates of any point on the spiral.

The point E is denoted by the special co-ordinates x_0, y_0.

The following general formulas are now given:

(1). $RL=A$.

(2). $\Delta_1=\dfrac{\frac{1}{2}L}{R}=\dfrac{L}{2R}=\dfrac{L^2}{2RL}=\dfrac{L^2}{2A}$. In minutes (2) becomes (3).

(3). $\Delta_1=\dfrac{3437.7468\,L^2}{2A}$

(4). $y=L-\dfrac{12L^5}{4A^2 1.2.3.4.5}+\dfrac{1680L^9}{16A^4 1.2.3.4.5.6.7.8.9}-\text{etc.}=L-\dfrac{L^5}{40A^2}$, nearly enough.

(5) $x=\dfrac{2L^3}{2A1.2.3}-\dfrac{120L^7}{8A^3 1.2.3.4.5.6.7}+\text{etc.}=\dfrac{L^3}{6A}$, nearly enough.

(6). $x_0=x_t-R_t$ vers. sin Δ_t.

(7). $y_0=y_t-R_t$ *sin* Δ_t.

(8). Tang. $D=\dfrac{x}{y-y_1}$. When deflection is turned off from P. S., $y_1=0$ and (8) becomes (9).

(9). Tang. $D=\dfrac{x}{y}$

D' is calculated for $y_1=200$ ft.

T=length of tangent GA

T_1=length of tangent GB, or tangent of circular curve of same radius (R_t) as the middle part of the curve (FF')

(10). $T_1=R_t\times$tang. $\frac{1}{2}\Delta$. We then have (11).

(11). $T=T_1+BM+MA=GM+y_0=(R_t+x_0)$ tang. $\frac{1}{2}\Delta+y_0$.

We now have all the measurements necessary to lay off the curve. Beginning at the P. S. we can turn off computed deflection angles for different points on the spiral or we can measure them off from the axes of co-ordinates from A as an origin, by computing x and y for such points. It is well to establish E (x_0, y_0) by measurement; and also F, which equals

x_t, y_t, for a length of curve equal to the degree of the central circular curve divided by the rate of change of curvature. When the spiral is so long or so obstructed that it cannot be run from one setting of the instrument at A, set up at a point 200 ft. along the tangent toward G, and turn off the deflections D'.

Table X gives values of the elements of a spiral varying 1 deg. per 40 ft. or $1\frac{1}{2}$ min. per foot. Points are taken for every 10 ft. on the spiral and the table is given as an example. By substituting in the foregoing formulas, convenient tables are easily worked out for any rate of change. The sum of the deflections for the circular arc should be $\frac{1}{2}\Delta - \Delta_t$ and

the length of the circular arc is then $\dfrac{\frac{1}{2}\Delta - \Delta_t}{\frac{1}{2}\text{ deg. of circular curve}} \times 100$ ft.

For spirals having central angles up to about 12 deg. (which corresponds to spirals of 300 to 380 ft. length where the rate of increase of curvature is 1 deg. per 40 to 60 ft.) the foregoing formulas give results which are practically exact, in fact so nearly exact that the discrepancies are not measurable with the transit. Beyond this, that is with spirals longer than would be used in good practice, there is room for hair splitting. The Holbrook spiral, developed by different methods, is the curve used in several field books, including "The Transition Curve," by C. L. Crandall, and "The Railway Transition Spiral," by A. N. Talbot.

Of General Application.—In order to change an old circular curve to one of the same degree but having spirals or transition curves of any form at the ends, the old track must, as has been shown, be thrown in all the way around the curve. The old track may be kept in place at the central portion of the curve, and nearly so all the way around, by increasing slightly the degree of the circular or central portion of the curve. In order to change a circular curve for one having transitions at its ends, in a man-

Table X.—Holbrook Spiral.

Spiral Increasing 1 Degree in 40 Feet.

$$RL = A = \frac{343774.68}{1.5} = 229183.1$$

L	Degree.	Radius $\left(\frac{229183.1}{L}\right)$	Δ_t $\left(\frac{L^2 \times 3437.7468}{2A}\right)$	x $\left(\frac{L^3}{6A}\right)$	y $\left(L - \frac{L^5}{40A^2}\right)$	x_o $\left(x_t - R_t \text{ versin } \Delta_t\right)$	y_o $\left(y_t - R_t \sin \Delta_t\right)$	D $\left(\tan^{-1} \frac{x}{y - o}\right)$	D' $\left(\tan^{-1} \frac{x}{y - 200}\right)$	L
Ft.	Deg. Min.	Feet.	Deg. Min. Sec.	Feet.	Feet.	Feet.	Feet.	Deg. Min. Sec.	Deg. Min. Sec.	Ft.
0	0 00	Infinity	0 00 00	0.0000	0.000	0.000	0.000	00 00 00		0
10	0 15	22918.31	0 00 45	0.0001	10.000	0.000	5.000	00 00 15		10
20	0 30	11459.15	0 03 00	0.006	20.000	0.002	10.000	00 01 00		20
30	0 45	7639.44	0 06 45	0.020	30.000	0.005	15.000	00 02 15		30
40	1 00	5729.58	0 12 00	0.047	40.000	0.012	20.000	00 04 00		40
50	1 15	4583.66	0 18 45	0.091	50.000	0.023	25.000	00 06 15		50
60	1 30	3819.72	0 27 00	0.157	60.000	0.039	30.000	00 09 00		60
70	1 45	3274.04	0 36 45	0.249	69.999	0.062	35.000	00 12 15		70
80	2 00	2864.79	0 48 00	0.372	79.998	0.093	39.999	00 16 00		80
90	2 15	2546.48	1 00 45	0.530	89.997	0.132	44.999	00 20 15		90
100	2 30	2291.83	1 15 00	0.727	99.995	0.182	49.999	00 25 00		100
110	2 45	2083.48	1 30 45	0.968	109.992	0.242	54.998	00 30 15		110
120	3 00	1909.86	1 48 00	1.257	119.988	0.315	59.996	00 36 00		120
130	3 15	1762.95	2 06 45	1.598	129.982	0.400	64.997	00 42 15		130
140	3 30	1637.02	2 27 00	1.995	139.974	0.499	69.996	00 49 00		140
150	3 45	1527.88	2 48 45	2.455	149.964	0.615	74.995	00 56 15		150
160	4 00	1432.39	3 12 00	2.979	159.950	0.745	79.992	1 04 00		160
170	4 15	1348.14	3 36 45	3.573	169.932	0.894	84.988	1 12 16		170
180	4 30	1273.24	4 03 00	4.241	179.910	1.061	89.985	1 21 02		180
190	4 45	1206.23	4 30 45	4.988	189.882	1.249	94.980	1 30 17		190
200	5 00	1145.91	5 00 00	5.818	199.848	1.457	99.975	1 40 03	91 29 59	200
210	5 15	1091.35	5 30 45	6.735	209.806	1.688	104.968	1 50 19	34 28 57	210
220	5 30	1041.74	6 03 00	7.743	219.755	1.941	109.960	2 01 05	21 24 14	220
230	5 45	996.45	6 36 45	8.848	229.694	2.219	114.949	2 12 22	16 35 34	230
240	6 00	954.93	7 12 00	10.053	239.621	2.523	119.937	2 24 00	14 14 14	240
250	6 15	916.73	7 48 45	11.363	249.535	2.854	124.922	2 36 26	12 55 14	250
260	6 30	881.47	8 27 00	12.782	259.434	3.212	129.905	2 49 14	12 08 13	260
270	6 45	848.83	9 06 45	14.314	269.317	3.601	134.885	3 02 33	11 40 08	270
280	7 00	818.51	9 48 00	15.984	279.181	4.020	139.863	3 16 23	11 23 56	280
290	7 15	790.29	10 30 45	17.736	289.024	4.471	144.836	3 30 42	11 16 08	290
300	7 30	763.94	11 15 00	19.635	298.843	4.956	149.806	3 45 33	11 14 07	300
310	7 45	739.30	12 00 45	21.664	308.617	5.474	154.790	4 00 54	11 16 37	310
320	8 00	716.20	12 48 00	23.829	318.403	6.031	159.730	4 16 48	11 22 45	320
330	8 15	694.49	13 36 45	26.134	328.137	6.628	164.686	4 33 13	11 31 40	330
340	8 30	674.07	14 27 00	28.582	337.837	7.259	169.633	4 50 10	11 42 55	340
350	8 45	654.81	15 18 45	31.179	347.500	7.933	174.576	5 07 38	11 56 09	350
360	9 00	636.62	16 12 00	33.929	357.128	8.651	179.511	5 25 38	12 11 08	360
370	9 15	619.41	17 06 45	36.836	366.700	9.414	184.440	5 44 10	12 27 38	370
380	9 30	603.11	18 03 00	39.904	376.229	10.223	189.366	6 03 15	12 45 31	380
390	9 45	587.65	19 00 45	43.138	385.706	11.079	194.265	6 22 53	13 04 39	390
400	10 00	572.96	20 00 00	46.542	395.126	11.968	199.162	6 43 05	13 24 37	400

ner not to change the length of the shifted track (so as to avoid cutting rails), the central or circular portion of the curve must be thrown outward at its middle and inward at its ends, thereby increasing the degree of curve; this method leaves the new curve as nearly as may be on the old ground. The central portion of the old curve may remain undisturbed by compounding at its ends, thereby increasing the degree of curve at those points. The treatment of these special problems, as well as numerous ones arising in the application of transition curves between the branches of compound curves, in different ways, will not be taken up. These problems the reader will find worked out in any of the text books heretofore mentioned.

The prevailing method of running out the elevation on transition curves has already been stated in defining the principal purpose of these curves. The track at the beginning of the easement, or at the tangent point, is made level transversely, and the elevation for the circular or main portion of the curve is developed with the easement, full elevation being used at the end of the easement or beginning of the main curve. In a few instances there are exceptions to this practice. On the St. Louis & San Francisco R. R. the form of easement is a tapering curve of 25-ft. chords and the development of the elevation begins on tangent a chord length in advance of the point of easement. The purpose of this arrangement is to give the elevation required for the first chord of the easement, at the tangent point, so as to be able to obtain the full elevation for each chord of the easement as it is reached by a train approaching from the tangent. Similar practice is in vogue on the Michigan Central R. R., where, also, the form of easement is a tapering curve. With the cubic parabola or any of the spirals it is plain that no question of the necessity of any such provision arises. In the largest practice the transition curves of the same road are of variable lengths, according to the degree of the main curve or

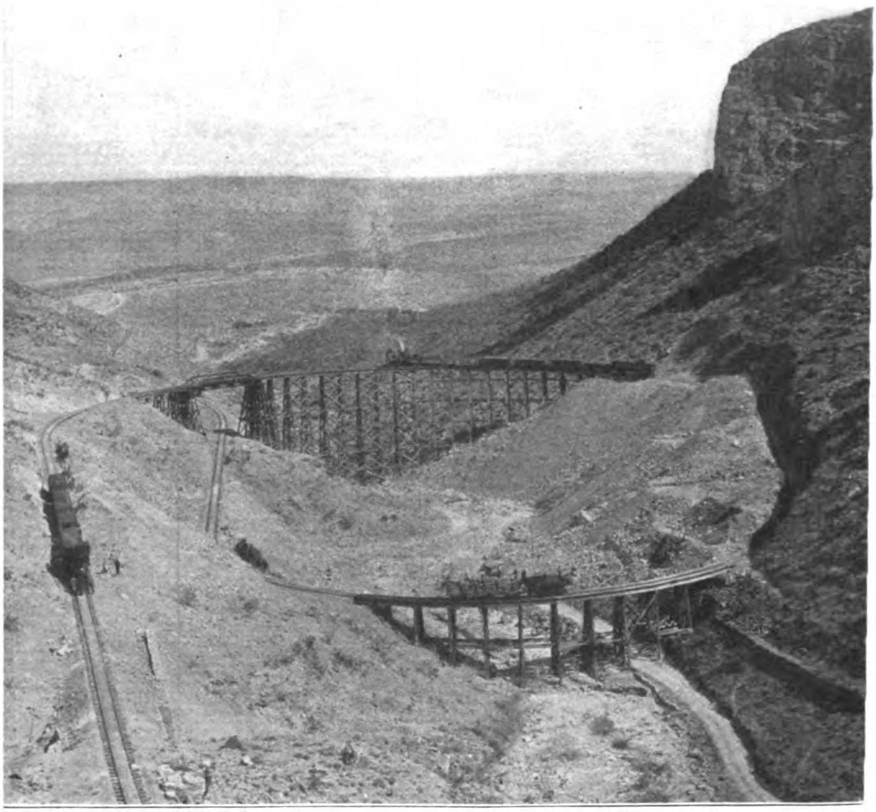
MICHIGAN CENTRAL R. R.—MIDDLE DIVISION.

CURVE NO. 10. SECTION NO. 31. CURVE TO LEFT.

Distance west of P. C. at which changes in elevation are to be made.	Elevation to give outer rail.	East end of curve is 117.8 ft. east of post 118½ miles from Detroit, and is opposite a stake marked "P. C." West end of curve is 86.0 ft. west of post 119 miles from Detroit, and is opposite a stake marked "E. C."	Distance east of E. C. at which changes in elevation are to be made.	Elevation to give outer rail.
FEET	INCHES	FROM EAST END OF CURVE THERE ARE	FEET	INCHES
0	¼	1st. 350.00 ft. of Easement .... Stakes 25 ft. apart	0	¼
25	½		25	½
50	¾	2nd. 206.75 ft. of 2° 31′ Intermediate curve .... Stakes 50 ft. apart	50	¾
75	1		75	1
100	1¼	3rd. 1800.00 ft. of 2° 32′ Central curve .... Stakes 50 ft. apart	100	1¼
125	1½		125	1½
150	1¾	4th. 176.33 ft. of 2° 33′ Intermediate curve.... Stakes 50 ft. apart	150	1¾
175	2		175	2
200	2¼	5th. 350.00 ft. of Easement .... Stakes 25 ft. apart	200	2¼
225	2½		225	2½
250	2¾	2883.08 ft. = total length.	250	2¾
275	3		275	3
300	3¼		300	3¼
325	3½		325	3½
350*	3¾	Elevation to give outer rail between points marked (*) is 3¾ ins.	350*	3¾

the elevation of the same, but in a few instances all the transition curves of a road are of standard or constant length, as was stated to be the case with the run-off of simple circular curves on several roads.

On some roads where transition curves are used it is not the practice to apply them to curvature that is easier than 1 or 2 deg., while on others it is the rule to ease all curves of whatever degree, even down to ½ deg., such being the practice with the Vandalia Line and the Michigan Central R. R. On the latter road each roadmaster and section foreman is supplied with a record of each curve under his charge, in the accompanying tabulated form.



Some Curves on the Morenci Southern Ry., in Arizona.

The Morenci Southern Ry., in Arizona, reaches Morenci through a narrow canyon, the natural grade of which is 6 per cent, and there are no side branches. The ascent of the railway on its maximum grade of 3½ per cent is accomplished by means of five complete loops, three tunnels and many very sharp horseshoe curves, locally known as "merry-go-rounds." On four of the loops the track crosses over itself on trestle, and in the other case the loop is made in a tunnel, on a sharp curve. The above view shows the fourth loop from and below Morenci, being only one mile distant, in an air line. The gage of the track is 3 ft., and there are some high trestles on 38-deg. curves.

CHAPTER VI.

SWITCHING ARRANGEMENTS AND APPLIANCES.

55. Turnouts.—A turnout, as the name implies, is an arrangement by which a car may pass from one track to another. The principal parts of a turnout are a switch and a frog, with a connecting piece of track called the *lead.* The rails connecting the switch with the frog, in both main track and turnout, are called *lead rails,* or the *main lead* and the *turnout lead.* A switch is a device for shifting the route at the entrance of a turnout. A frog is a union of two rails which cross each other, in such a manner that a wheel rolling along either rail will have an unobstructed flangeway while passing the other rail. The principle of the turnout is to cross the adjacent rails of the two tracks at the frog and to extend them beyond, so as to bring all four rails of both tracks near together to a point called the *point of switch* or *toe,* where the rails usually stand 5 or 6 ins. apart between gage lines. Then by means of two rails, each having one end free to move, a car may be switched from one track to the other. These two rails constitute the *switch,* and are usually called the *switch rails* or *moving rails.* It is usual to call the whole arrangement from switch to frog, "the switch," but the proper term to use is *turnout.*

In the *stub switch* the two rails of each track are cut squarely off at the toe and the switch rails are thrown so as to meet the fixed ends of the lead rails of either track squarely end to end. If the ends of the rails are cut off at a bevel, so as to lap by slightly when thrown, the switch is called a *lap switch.* The *point* or *split switch* is made up of a rail from each track, both rails being tapered a long way back and connected together, so as to throw alongside the through rail of either track. In this switch one rail of each track is cut off squarely at the heel and the other rail is left continuous; that is, one main-track rail is continuous, and one rail of the side-track is continuous with the main-track rail, being bent at the point of switch so as to turn from main track into the side-track. The fixed end of the switch is called the *heel,* the movable end to *toe.* In a stub switch, the heel is the end of the switch farthest from the frog; in a split switch, the end nearest the frog. The toe of the split switch is the point of switch. The distance from toe to heel in either case is called the *length of switch.* The distance over which the free end of the switch is moved is called the *throw* of the switch. In stub switches the throw must obviously be the same as the distance between the gage lines of the fixed rails in main track and turnout at the toe; but in point switches it need be only enough to give room for moving the point rail out of the way of the wheel flanges; four inches is sufficient. The turnout, between the switch and frog, is usually made a simple circular curve.

There is another switch used to some extent, known as the *Wharton switch.* With this switch both main track rails are unbroken and continuous. The switch rails consist of one point or grooved rail, which works against the main-track rail on the side opposite the frog, and another rail to which it is cross connected, working against the outside of the main-track rail on the frog side. This movable rail on the frog side has a sloped top which runs up higher than the main rail against which it is thrown and lifts the wheel so that its flange passes above and across it to the turnout lead rail. Stub and split switches are the ones in most general use.

56. Stub Switches.—Formerly the stub switch was the one the most used. It is durable, serviceable, and there is nothing in its make-up that is particularly delicate, but owing to certain objectionable features it has gone out of use for main-line service on nearly all of the heavy-traffic roads. Among these objectionable features or points of weakness are the frequent settlement of the headblock, due to the heavy pounding of the wheels at the open space which must be left at the toe; and the "tight switch," due to expansion and creeping of rails in hot weather. Quoting from a committee report to the New England Roadmasters' Association in 1890, "the stub switch, with its open joint in winter and tight joint in summer, with a loose headblock to be tamped every few days," is well to the point. The derailment of trains which trail (approach from the direction of the frog) an open or misplaced stub switch, is, however, the dangerous and, therefore, the most objectionable, feature. Although the point switch was in use at an early day, still the preference for the stub switch was for many years so strong that it was in some cases equipped with a rerailing device to prevent wheels from leaving the track when trailing the switch wrongly set. One arrangement of this kind was the Tyler switch, used to some extent at one time. It consisted of a short guard rail bolted to the gage

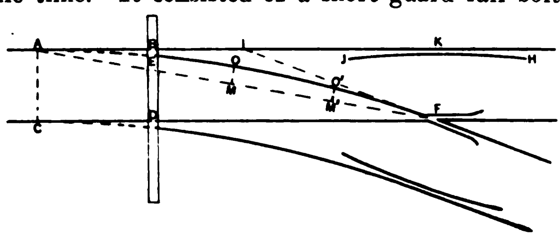


Fig. 67.—Diagram of Stub-Switch Turnout.

side of each moving rail and flared to cover the end of the stub rail, with an inclined plane bolted to the outside of the rail. With this arrangement wheels trailing the switch wrongly set would be caught on one side of the track by the guard rail and on the other side by the inclined plane and guided to place on the moving rails.

Measurements for Stub-Switch Turnouts.—A stub switch on straight track is shown by diagram in Fig. 67. $A B$ and $C D$ constitute the switch or moving rails; $B E$ is the throw; A or C is the heel; B or D is the toe or point of switch; AB is the length of switch; F is the point of frog. The distance from D to F is called the *lead;* from C to F, the *total lead.* The whole turnout from A to F is usually made a simple circular curve, as already stated, and in that case the point A is easily found by producing the line of the turnout rail of the frog straight ahead until it intersects the opposite rail at I. $I A$ must be equal to $I F$, because the two tangents from the same point to any simple circular curve must be equal. The formulas for the various measurements of a stub-switch turnout are simple and are given below. A geometrical demonstration of the same, prepared by the writer, was published in the Railway and Engineering Review for Dec. 31, 1897.

The distance CF—that is, the distance from heel of switch to frog point, or the "total lead"—is twice the frog number times the track gage, or $2\,n\,g$.

The radius of the center line of the turnout (r) is equal to twice the square of the frog number times the gage, or the total lead times the frog number. The formula is therefore $r=2n^2g$. The radius of the outer rail of the turnout curve is then $2n^2g+\frac{1}{2}g$.

The length of switch (AB) or the distance from heel to toe, in feet, is twice the frog number times the square root of the product of the throw and the gage, both expressed in feet [$2n\sqrt{(gt)}$]; or it is equal to the square root of twice the product of the radius and the throw in feet, or $\sqrt{(2\ r\ t)}$.

The length of the chord AF of the outer rail of the turnout is $g\sqrt{(4n^2+1)}$.

These formulas are easily understood and used by any person acquainted with common arithmetic. As an example, let us compute the distances from heel to point and the length of switch rail for a turnout with No. 8 frog and a switch with 5-in. throw. The distance heel to point$=2\ n\ g$ $=2\times8\times4.708=75.328$ ft. Length of switch in feet$=2n\sqrt{(g\ t)}=2\times8$ $\sqrt{(4.708\times{}^5/_{12})}=22.4$ ft.

If the toe of the frog or the beginning of the straight portion of the frog leg is taken as the end of the lead curve, the "total lead" for the stub-switch turnout then becomes $2n(g-k\ \sin\ F)+k\ \cos\ F$; and the radius, $2n^2(g-k\ \sin\ F)$; where k represents the length of the straight portion of the leg in advance of the point of frog, and F the frog angle.

Some trackmen line the outer lead rail quite well by the eye, but it can be located to the exact curve with but very little trouble by stretching a string from heel to frog point and laying off the middle ordinate equal to $\frac{1}{4}$ the track gage, and the quarter ordinates $\frac{3}{4}$ of this, or ${}^3/_{16}$ of the track gage. To be exact, the middle ordinate of the center line of the turnout is $\frac{1}{4}g$, and that of the outside rail slightly more; but the difference is not as great as ${}^1/_{16}$ in. in any case. In practice, however, in any turnout from straight track, regardless of frog number, the middle ordinate MO (Fig. 67) may be taken at $\frac{1}{4}g$, or $14\frac{1}{8}$ ins., and the quarter ordinate $M'O'$ at ${}^3/_{16}g$, $=10\frac{5}{8}$ ins. The middle ordinate of a chord drawn from E to F, that is from toe to frog point, is always 7 ins., and the quarter ordinate, $7\times\frac{3}{4}=$ $5\frac{1}{4}$ ins., for any length of lead or any frog number, where the main track is straight. Some use the middle ordinate of this chord in preference to the one from heel to point. Still another method of lining the lead curve is to lay the outer rail by offsets from the main-line rail to which it is tangent. The offset at the middle point (O) is $\frac{1}{4}$ of the gage ($\frac{1}{4}g$), at the quarter point it is ${}^1/_{16}g$ and at the third quarter (O') it is ${}^9/_{16}g$.

Originally the standard throw for stub switches was 5 ins., but for the heavier rails with wider heads which have come into service a larger throw is necessary in order to provide a flangeway of sufficient width. Where the width of the rail head exceeds $2\frac{1}{4}$ ins. the throw should be at least $5\frac{1}{2}$ ins. Table XI (see index) gives the necessary measurements for stub-switch turnouts with frogs of different angles, including the length of switch, for both a 5-in. and $5\frac{1}{2}$-in. throw. In connection with stub switch measurements notice should be taken of the fact that the length of switch corresponding to a throw of 5 ins. and a No. 11 frog, or frog of higher number, exceeds 30 ft.; and for a throw of $5\frac{1}{2}$ or 6 ins. the length of switch reaches 30 ft. with a frog of smaller number. For this reason it is not practicable to have the full length of free switch rail with frogs of the higher numbers (say No. 9 and above) unless rails longer than 30 ft. are used. In practice, not to exceed 25 or 26 ft. of a 30-ft. rail, or the length of switch corresponding to a No. 9 frog, would be left free. Hence the curvature of the switch must sometimes be made sharper than that of the lead.

In laying a turnout from curved track the lead distances may be taken the same as for straight track, for ordinary frog numbers, without noticeable error. If the turnout be *with* the curve (that is, from the inside of the curve), its degree, corresponding to a given frog number, will be increased, over that for straight track, approximately by the degree of curve of main track. If the turnout be *against* the curve its degree, corresponding to a given frog number, will be decreased, from that for straight track, approximately by the degree of curve of main track; and when the curvature of the main track becomes equal to that which the turnout would have in straight track, for a frog of given number, then the turnout becomes straight. In order to find the number of the frog required for a straight turnout from the outside of a curve of given degree, we may consider the straight track as the main line and the curved track the turnout, and then find the frog required for a lead curve from straight track equal in degree to that of the curvature given. In that case the radius and gage are given to find the frog number. From a previous formula we have $r=2n^2g$; from which $n=\sqrt{(r\div 2g)}$.

In lining the lead rails of turnouts from curves the middle and quarter ordinates of the outer rail are different from those used for leads from straight track. In Table XI there is a column giving the rate of change in the ordinate per degree of curvature of main track. When the turnout is from the outside of the curve the ordinate should be decreased at this rate, and when it is from the inside of the curve the ordinate should be increased at the same rate. This rate of change is found by dividing the ordinate for straight track by the degree of turnout curve for straight track which corresponds to the number of the frog used.

The length of switch in turnouts from curves is also practically the same as in turnouts from straight track. The length of switch, however, need not always be laid down to exact measurement, since it can be determined easily by trial, by throwing it first to main track and then to switch, backwards and forwards, as the rails are being spiked at the heel. Owing to the fact that some rails are stiffer than others, the switch will sometimes curve better if not made exactly the computed length, being lengthened or shortened by spiking less or more ties, respectively, as it seems to curve best to meet the fixed ends of the lead rails.

In turnouts from the inside of curved track the curvature of the turnout runs up pretty fast as the curvature of main track increases, and unless frogs of the higher numbers are introduced the limit is soon reached. Although freight cars and some switching engines may be successfully operated around curves as high as 60 deg. or more, the limit for ordinary locomotives, where guard rails are not used, is about 16 or 17 deg. So frogs of higher number than would ordinarily be used on straight track may come into use in turnouts from the inside of curves, but in turnouts from the outside of curves the reverse is true; that is, frogs of the lower numbers are brought into service.

57. Laying Stub-Switch Turnouts.—As a rule but few turnouts are put in when track is first built, and hence the work of laying turnouts usually involves tearing up the old track. A matter of importance in laying a turnout is to do it with a minimum cutting of rails. Where the track is laid with square joints and the frog is of such angle and length that it can go in, either behind two 30-ft. rails and make the proper lead distance, or else with one 30-ft. rail and a piece, so as to take up just 60 ft. and make the proper lead distance, a stub switch turnout can be put in by cutting only one main rail—that to make room for the frog. By the latter arrangement one rail additional must be cut for the turnout between switch and frog, while with the former it need not. The deviation of a few feet either way from the exact lead distance can be made without materially impairing the lead curve; still it is just as easy to make a frog of one angle as another, and it is of no consequence if the frog number be fractional. In standard practice the exact distances may be had as well as not, and by standardizing there is a saving of expense, as then fewer frogs need be carried in stock. This matter can easily be provided for by a little calculation. Suppose, for instance, that the frog is made a standard length of 10 ft. and that its point is 6 ft. from its heel and 4 ft. from its toe. Let the throw be 5 ins. Then if the frog be put in behind two 30-ft. rails, from the headblock, the lead distance will be 64 ft. and the frog angle corresponding to this lead, 5° 55′; the number is 9.67. If a frog of the same length from point to heel and toe was put in within the 60 ft., the lead distance would be 54 ft. and the frog angle required would be 7° 01′; the frog number corresponding is 8.16. Thus by making the frog of standard length each way from its point, a standard lead distance by something less or more than 60 ft., as the case may be, can be used by making the frog angle to suit this lead. One or both of the frogs calculated in this manner might be chosen as standard, both being about equally convenient for laying; say No. 8.16 where the shorter lead would answer, and No. 9.67 where the longer lead would be desired. The former gives a turnout curve of 9° 8½′, the latter 6° 30½′. To purposely make frog numbers integral, simply for the sake of it, is of no particular convenience. On the Chicago & Northwestern Ry. the scheme for avoiding the cutting of closure rails (the standard frog numbers with one exception being integral) is to vary the lengths of the frog legs to fit in with closure rails of standard length—24 ft., 28 ft. or 30 ft.—as explained in connection with the work of laying point switches (§ 69).

After the location for the headblock has been determined upon and the place to be occupied by the frog has been noted, the first thing to be done is to put in the switch ties, if such are to be used. If there is time between trains, the main-track rail on the frog side had better be taken up for 60 feet and the rail on the other side blocked up, in order that the old ties may be taken out without so much digging. In this way the ties may be changed in half the time required to dig between each two and take them out in the usual manner; besides, at least one rail on that side must be taken up anyway, to let in the frog. If there is not time between trains, one or two ties may be removed at a time, as opportunity offers, and replaced with switch ties, but such rails as must be taken up when the frog goes in should not be full spiked; on straight line, it is well enough to simply tack down part of the spikes, not driving them all the way down. Care should be taken not to dig into the beds of the old ties any more than will be sufficient to let in the switch ties snugly, as thereby much tamping can be avoided. If short ties (8-ft. ties) are to be used in the turnout, the first thing to do is to lay a guard rail opposite the place where the frog is to go in; and in any case the guard rail can be and should be laid before the frog is placed. If the rails on hand for laying the turnout are not suitable for use in main track, then the main-track rails must be taken up and cut. In any event, frog, guard rail and long switch ties, when used, go in first, and after these the headblock.

By using blocks of the same thickness as the headshoes, or slightly less, the headblock may be put in without the headshoes (splicing all joints in the rails) and be so left for any length of time, in case the work is interrupted at this point; but lead rails should not be spiked down until after the switch ties have been tamped to surface, the main track between switch and frog put in line and headshoes in place. When short ties instead of switch ties are used in the turnout, the track between headblock and frog should be put to surface, if not already so, before the short ties are laid.

The remainder of the work may be done in such order of arrangement as seems most convenient. Lead rails may be bolted together and to the frog, and lie in the track secured by tacking a spike on a tie near the toe of the switch, so that the loose end may not be swung around by any means and get in the way of the flanges of passing car wheels. Switch rods may be placed on the moving rails and the rails may then be partially spiked down again, if there is not time between trains to connect them to the stand and secure it. When this is done braces should be put down temporarily to keep the rail ends in place on the headshoes. Angle bars or fish plates placed endwise against the web of the rail and spiked to the headblock, through the bolt holes, and at the end, serve well for this purpose. The switch rods are driven on from the headblock end of the moving rails, blocking up the rails a tie or two back from the headblock and starting all the rods on together, if they are nearly enough of the same gage (as they should be) to allow it. The moving rails are then blocked up at their ends and the rods driven to place. There is no need of taking splices from both ends of the moving rails in order to get the rods on, or of pulling more spikes than to make free the proper length of switch rail. Switch rods should, as a general thing, be equally spaced; but after throwing the moving rails and trying a few times it is sometimes found that they can be changed to give the rails a better curvature than where all the rods are equally spaced; besides, the spacing of the ties will not always admit of even spacing of rods. Moving rails of stub switches should always be the full length of 30 feet, so as to avoid having a joint near the heel. If there is a piece of rail to go in on that side of the headblock it should be put in back of the moving rails. With the frog and guard rail in, switch rods on, and moving rails connected to the stand, in its place, the main-track part of the work is done.

Where track is laid broken jointed, more cuts must generally be made than where the joints are even. If the frog is No. 6, 7 or 10 it is generally better to locate the headblock underneath a joint on the side opposite the frog. With a frog of any other number it is usually better to locate the headblock under a joint on the frog side of the track, as by so doing, some cuts, to avoid putting in short pieces, will be saved. Where the headblock is located under a joint there will frequently be sufficient expansion space in the joints each way to close up some and allow room for the necessary opening between the rails at the headblock; if not, then a piece must be cut off, If hack saws are used, any length of piece can be taken off, but it is difficult to notch and break off a piece shorter than 3 ins. with hammer and track chisel. Whatever length of piece is cut off, there should not be left a clear space of more than ½ in. at the headblock, but the excess opening should be distributed among the joints each way. Where a rail must be taken out to be cut, so as to give more opening at the headblock, the moving rail should not be cut unless the end is battered. It is easier to take out one of the rails behind the moving rail. Ends of moving rails on headblocks should be directly opposite each other; that is, squarely across the track from each other; and no lip should be permitted to exist. Half fish plates are sometimes bolted to the ends of stub switch rails, to strengthen the web and prevent the end of the rail from being battered down. This practice was quite common when iron rails were used.

In setting a switch stand the connection with the head or neck rod should be made before the stand is secured to the headblock, and the moving rails should be in the main-track position, without lip. If the stand is then made fast and there is no lost motion, and the throw is right, there will be no lip when the switch is thrown to the turnout.

Lip is the lateral projection of a rail end at a joint; it is most bothersome and dangerous at the headblocks of stub switches. It may be caused between switch and lead rails by improper setting of the switch stand or of the headshoes; by improper throw; by wearing of parts in the stand or of the bolts in connecting joints; or by the switch rail becoming loose through wear in the head rod connection therewith. The remedy for the first cause is, of course, to reset the stand or headshoes. Oftentimes proper care is not exercised to make the gage at the stub ends of the lead rails in main track or turnout correspond with the gage between the ends of the switch rails. The best way to prevent improper throw—that is, a throw not corresponding to the movement required by the distance between the lead rail ends in the headshoes—is to inspect all switch stands and headshoes before sending them from the storeroom. Herein lies the value of having everything standard. Lost motion must be taken up. Sheet tin cut from old tomato cans comes handy to wrap around bolts or to put in bearings to take up lost motion, when bolts of larger size or new parts are not on hand. Rails loose in switch rods can be keyed.

Lead rails should be curved before they are laid; otherwise it is difficult to prevent them from twisting the headshoes around when attempting to spring a curve into them. Both legs or ends of frog rails are usually cut off at the same length, and as the turnout lead is 2 or 3 ins. longer than the main-track lead, where a frog is put behind two 30-ft. rails there will be an opening of corresponding length in the turnout lead. To avoid leaving the rails open at this point or cutting rails to close the space it is usual to fill the opening with a short piece of rail which trackmen call a "dutchman." The ends of all cut rails meeting at a splice should be drilled, so that all splices in both main track and turnout may be full bolted. By putting the cut ends of the rails into the headshoes the drilling of some holes may be avoided. To resist creeping as much as possible the splices between frog and switch and at all joints in the vicinity should be slot-spiked, and to permit this the switch ties must, of course, be spaced accordingly.

When laying a turnout it is well to bring to the site an assortment of spare pieces of rails if the same happen to be conveniently at hand. When such is done it is often the case that combinations of pieces can be selected which will save cutting rails. It is well for section foremen to keep a list giving the exact length of each spare piece of rail on the section, and the location of it. By a piece of rail is meant, of course, any piece shorter than the standard rail length. Every time a cut can be avoided there is a saving of time and usually some waste of material is avoided.

There are so many little details connected with the work of laying a turnout, and circumstances may vary so much, that it is not possible to describe the work except in a general way. Much must be left to the judgment of the foreman in charge. Shortly after a road has been built, when there are many turnouts to go in, and when many of the foremen are new and inexperienced, it is economy to select one or two foremen who are experts at laying turnouts, and give them crews of their own, to put in all the turnouts to standard requirements. In order to make fair headway, where trains must be dodged, the work must be crowded a little, at times; but unless men have had some experience they cannot do this. One or two crews engaged in laying turnouts soon become skillful at the work, whereas, if they are laid on each section by its own crew the men just begin to learn how when they get through, and that at the expense of the company, both in the cost and quality of the work. It is well to make up the extra crew or crews engaged at this work by taking a man or two from each section, for a few sections each way from where the work is being done. When not bothered much by trains, a good foreman and six fair trackmen can put in either a stub or a split switch turnout in one day of ten hours, including the removal of old track ties and putting in switch ties. The remainder of what is said concerning the work of putting in the different parts of a turnout is included under discussions of the several parts of a turnout as they are separately taken up.

58. Frogs.—A frog, of any of the kinds in general use, is made of four pieces of rail properly shaped and held together by some device or arrangement of minor parts. Figure 68 shows the principal parts of a rigid frog and the conventional names for the same. The pieces of rail *A B* and *C D* are called the *wings* or *wing rails.* The ends *B* and *D* are flared 3½ to 4 ins., in a length of 10 to 15 ins., to serve as a guard for the wheel flanges. The portion *H K L* is the *tongue,* it being usually about ½ in. thick or wide at the end *H,* and sometimes chamfered off about $^1/_{16}$ in. at the corners. The imaginary point *P,* where the gage lines of the frog intersect, is the *point of frog* or simply *the point;* the blunt end *H* is the *point of tongue* and not the point of frog; it is also quite commonly called the *half-inch point.* The

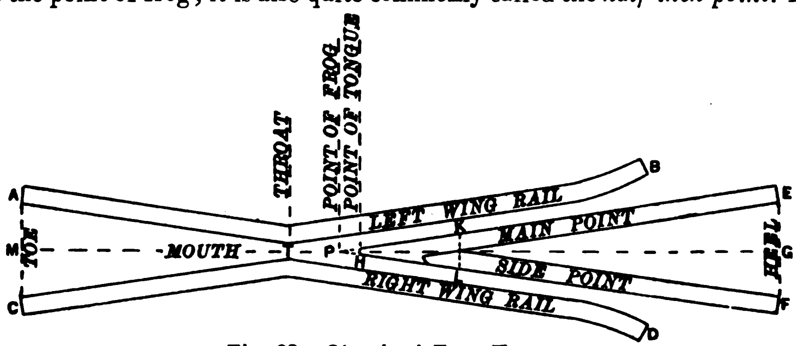


Fig. 68.—Standard Frog Terms.

ends *A* and *C* are called the *toe* of the frog; the ends *E* and *F,* the *heel.* The open portion *T,* where the wings are nearest, is called the *throat,* and sometimes the *knee.* The space between the toe and the throat is called the *mouth.* The spaces between the wings and the pieces *H E* and *L F* are the *channels* or *flangeways. H E* and *L F* are made straight and are called the *point* pieces; *H E* is the *main point* or *long point* and *L F* the *side point* or *short point. H E* is supposed to be used for the main track, and hence frogs made in this way are known conventionally as right-hand or left-hand, according as the side point piece is on the right or left side as one faces the point. The side point, however, is usually supported by the rail flange of the main point and used as a main-track or side-track rail indifferently, so that with rigid frogs it is not usual to make a distinction between rights and lefts. Some prefer to use the side point for main track, for the reason that if it is weaker than the main point it will receive severe treatment from the false flanges of badly worn tires, if placed on the turnout side.

In the process of the manufacture of the frog the point pieces should be planed down cold and not heated and forged. A dovetail joint between main and side point pieces is preferable to a straight joint without notching. The point pieces should be securely riveted together, through the webs, with not smaller than ⅞-in. rivets. In order to avoid drawing the temper of the metal the wing rails should also be worked cold, or heated no higher than is really necessary when they are bent. The bending should be to the arc of a small circle and not to a sharply defined angle. The throat is necessarily a trifle wider than the channels converging thereat, even if it is assumed that the wings are bent to an angle; this for the simple reason that the measurement of the throat is not made perpendicularly to the direction of either channel. As the wings are bent to an arc the throat must needs be somewhat wider still, and therefore appreciably wider than the channels. As it is sometimes necessary to find the point of frog it is a good idea, if the construction of the frog will admit, to indicate this point by a punch mark or by a cross cut with a cold chisel, on the filling or plate.

The angle of the frog is the angle $K\ P\ L$ or $E\ P\ F$. The *frog number* is the rate at which the rails forming the frog diverge in proportion to its length; it might also be correctly called the proportion of the frog. It may be found by dividing the distance from point of frog to heel by the spread at the heel, between gage lines ($P\ G \div E\ F$); or by dividing the length of the frog, over all, by the sum of the distances between gage lines at heel and toe, or on both ends—that is, $M\ G \div (E\ F + A\ C)$. Example: if a frog is 9 ft. long and the gage sides of the rails are 7 ins. apart at the toe and 5 ins. apart at the heel, then the frog number $= (9 \times 12) \div (7+5) = 9$. It is more usual to denote a frog by its number than by its angle, and the angle is usually made such that the proportion or number is an integral number, although there is no particular reason why it should necessarily be so.

A convenient way of ascertaining the frog number when no measuring instrument is at hand is to cut a stick the length of $E\ F$ and apply it to the distance $P\ G$. This distance expressed in lengths of the stick is, of course, the frog number. The number of a frog is 57.3 deg. or 3438 min. divided by the frog angle; or, conversely, the angle of a frog is 3440 min. divided by the frog number. Trigonometrically expressed, the number is half the cotangent of half the frog angle, or $n = \frac{1}{2} \cot \frac{1}{2} F$.

The established rule for finding frog numbers is as above stated. Nevertheless, some of the manufacturers consider the frog number to be the ratio between any distance on gage line and the spread at that point, as $P\ E \div E\ F$ (Fig. 68) or $P\ A \div A\ C$. This makes the frog number $\dfrac{1}{2 \text{ Sin } \frac{1}{2} F}$ (or practically $\dfrac{1}{\text{Sin } F}$ for frogs of ordinary angle). The difference between this value and $\frac{1}{2} \cot \frac{1}{2} F$ is so small that it is not worth taking into account.

Number 9 and No. 10 frogs are the ones in largest use in main track. In yards Nos. 7 and 8 are most frequently used, with No. 7 perhaps in the lead.

Rigid Frogs.—Frogs are of two kinds—rigid or stiff-rail frogs and spring-rail frogs. In a rigid frog all the parts composing it are supposed to be rigidly connected. The parts of both rigid and spring-rail frogs are joined together in three different ways: (1) by placing filler blocks between the pieces of rails and holding them together with bolts passing through the webs; (2) by riveting the flanges of the pieces of rails to a plate; and (3) by clamps or by clamps and wedges. Figure 69 shows a bolted frog; Figure 70, a riveted frog; and Fig. 71, a clamped frog, all being common types. Of the three ways the bolted frog gives the best satisfaction, if it is properly made. The base of the main point piece at and near its end should be planed to take a bearing on the flanges of the wing rails, as shown sectionally in Figs. 69 and 71. The base of the side point should, in the same manner, be planed to rest upon the flange of the main point piece, but unless the frog bolts are kept tight the support from these parts cannot be maintained satisfactorily, for the bearing is rapidly worn away after the parts get loose. Without some means of support independent of the frog bolts it cannot be expected to hold the tongue to place under load. In forming the point pieces the full web support should be carried to the extreme end of the piece. In order to do this it is necessary to bend the end of the piece sufficiently to bring the web over to meet the line of the planing. An example of such bending is shown by the broken lines illustrating the webs of the point pieces in Fig. 74. Additional support for the tongue should be obtained by shaping the channel filling to a snug fit under the head projections. The end of the tongue is sometimes made as thin as $\frac{3}{8}$ in., but seldom thinner. The end of the tongue, above the filling, is sometimes cut off to a sloping edge (Fig. 69) instead of a vertical one.

The bolted frog usually has 7 bolts. They should be 1 or $1\frac{1}{8}$ ins. in diam., according to the size of the rail, and the holes should be drilled perpendicularly to the axis of the frog; that is, perpendicular to the line *MG*, Fig. 68. The specifications of some roads require that the bolts of rigid frogs shall be set perpendicular to the main-line rail, but such increases

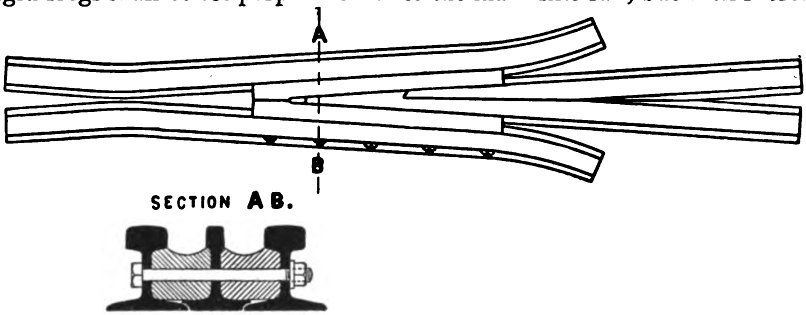


Fig. 69.—Rigid Bolted and Filled Frog.

their angularity with the turnout rail. The drillings for the bolts of spring-rail frogs are made perpendicular to the main-track rail or gage line.

Formerly the channel filling of frogs was made of cast iron, but wrought iron or rolled steel is preferable, and these are now the standard materials for this purpose. Cast filler blocks are sometimes made in one solid forked-like piece which straddles the tongue and fills both channels. The Elliot Frog & Switch Co. accomplishes the same end with wrought iron and steel filling by welding together the two pieces ahead of the point. Another method of forming solid filling, in practice to some extent, is to cast-weld it in place after the rail pieces of the frog are bolted together or otherwise assembled. The filler blocks should be machined to fit snugly between the rail pieces and they should extend from the flare of the wing rails to 6 or 8 ins. ahead of the point. Cast beveled washers are used to provide an even bearing for the bolt heads and nuts. The throat of a bolted frog should, for strength, be filled and bolted. Usually a 6-in. filler is placed at this point, but in Fig. 72 is shown a frog which has been used by the Lake Shore & Michigan Southern Ry. having a throat

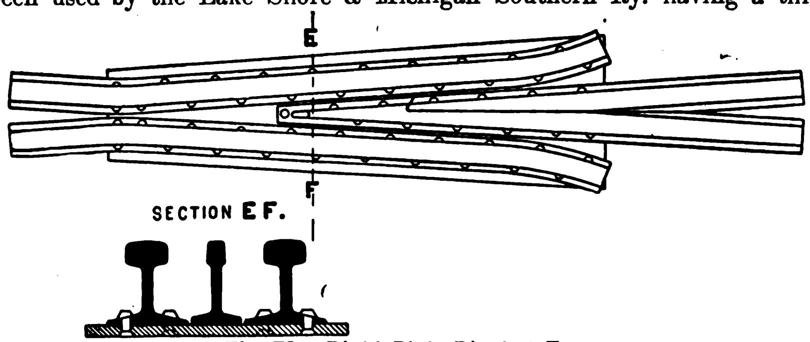


Fig. 70.—Rigid Plate-Riveted Frog.

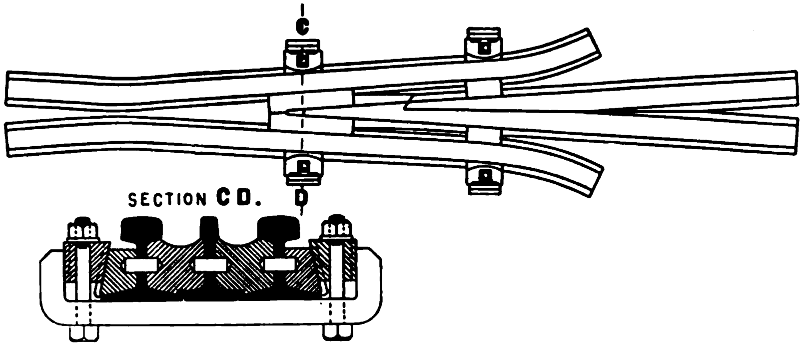


Fig. 71.—Rigid Clamped Frog.

filling block extending a sufficient distance into the mouth to serve the purpose of a foot guard. Blocks are also placed at the flare of the wing rails for the same purpose, the whole arrangement contributing very much to increase the rigidity of the frog.

The pieces of rail in a plate frog are secured to the plate by two rows of rivets, staggered, and sometimes countersunk on the under side. The plate used on different roads varies in thickness from $\frac{5}{8}$ in. to 1 in., $\frac{3}{4}$ in. being quite common. The plate should be at least 5 ft. long, and no wider than to allow for proper security in riveting, so as to discommode tamping as little as possible; for this purpose the plate may be cut with the long edges parallel with the wing rails (see Fig. 70) rather than rectangular. The rivets should be about $\frac{3}{4}$ in. in diam. Frogs constructed on tie plates, and other frogs which have tie plates riveted to them, are in use to some extent to prevent cutting into the ties. Either arrangement, however, can hardly be considered an improvement, for the separate tie plates when substituted for the ordinary large plate do not make so rigid a frog; and so far as the purpose of a tie plate is concerned, it is just as well, and perhaps better, not to attach the plates to the frog, since they may then be shifted

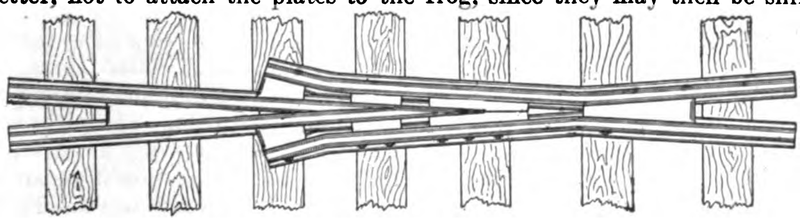


Fig. 72.—Frog with Mouth and Heel Filling, L. S. & M. S. Ry.

to suit the positions of the ties; otherwise the ties, if already laid, as in renewing a frog in an old turnout, might have to be shifted to suit the positions of the plates. As in other frogs, the point rails of plate frogs should be riveted together.

The pieces of rail in a clamped frog, also known as a yoked frog, are held in two ways: (1) by wedges which are driven against the web of the rail and held in the clamp by keys, or else by wedges which are held and adjusted by bolts (the better method) which draw them to a close fit, as in Fig. 71; and (2) by solid clamps or yokes which engage the frog rail pieces directly, by a close fit around the rail flange and against the web, the clamps being held to place by adjustable side rods that pass through the clamps and are made fast to the wing rails. One well known example of this type is the Strom frog, Fig. 73. The side or stay rods in this case hook around the ends of the wing rails. As the clamps wear loose they are driven on further and held against slipping back by following up with spring cotters on the rods. The fillings and wing rails are held against slipping by countersinking the heads of rivets into the fillings. No bolts pass through either the rails or filling pieces. Another frog of this type is the Ramapo yoked frog, Fig. 74. The yokes or clamps are adjustable by means of stay bolts extending parallel with the wing rails. The Weir clamped rigid frog has two steel clamps 4 ins. wide by 1⅛ ins. thick, and is tightened by means of two steel wedges. The filling blocks at each clamp (Fig. 75) are secured by a long through pin. But few claim to obtain satisfactory service from the clamped frog. The clamps work loose in spite of the utmost care to keep the wedges screwed or driven on tightly. In laying the frog the switch ties must be spaced to dodge the clamps or else they must be notched to let the clamps into the tie. It is not, therefore, a convenient frog to use where switch ties are already in or where another style of frog has been taken up, as some respacing of the ties is usually necessary. Clamped frogs have too many parts, are nearly always

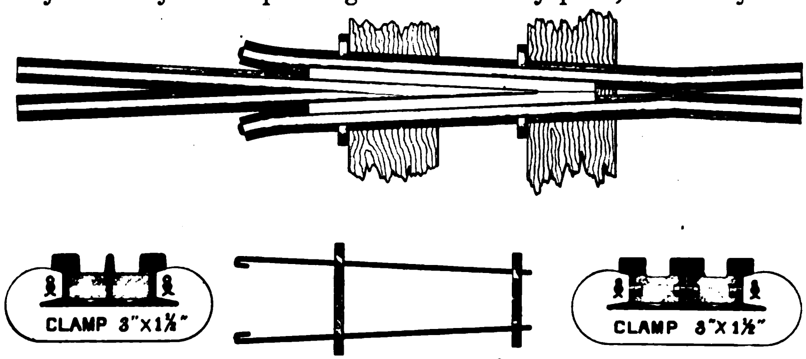


Fig. 73.—Strom Clamped Frog.

loose, and on general principles, really possess the least merit of any of the three forms. As expressed by vote in the annual convention of the Roadmasters' Association of America, in 1897, 29 preferred the bolted and filled frog, 9 the plate frog and 7 the clamped frog. A clamped frog is stiffened and improved by placing a clamp and filling block at the throat.

By combining the principal features of plate and bolted frogs, all weak points of both are overcome and a very stiff and durable frog is produced. An ordinary bolted frog is riveted to a steel plate. The plate will keep the tongue up to place and the bolts will keep the wings from working loose and shearing the rivets. This style of frog is now extensively used on roads where rigid frogs are preferred. As made for the Pittsburg & Western and Baltimore & Ohio roads, the wing rails are not riveted to the plate , but are held by the bolts only. The rivets which hold the frog to the plate are passed through the filling, as shown in Fig. 76. This arrangement permits the removal and renewing of the wing rails without cutting the rivets. One feature in the maintenance of plate frogs not to be overlooked is the fact that the plate does not wear out with the frog, but may be used over and over.

There is another device not answering exactly to the description of any one of the three foregoing types, known as the "U-plate" frog. It is made principally for use with rails not exceeding 60 lbs. per yard. The wing rails are bolted to the point pieces by means of heavy steel U-bars,

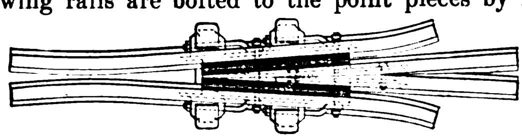


Fig. 74.—Ramapo Yoked Frog.

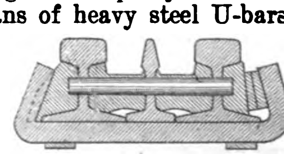


Fig. 75.—Weir Frog Clamp.

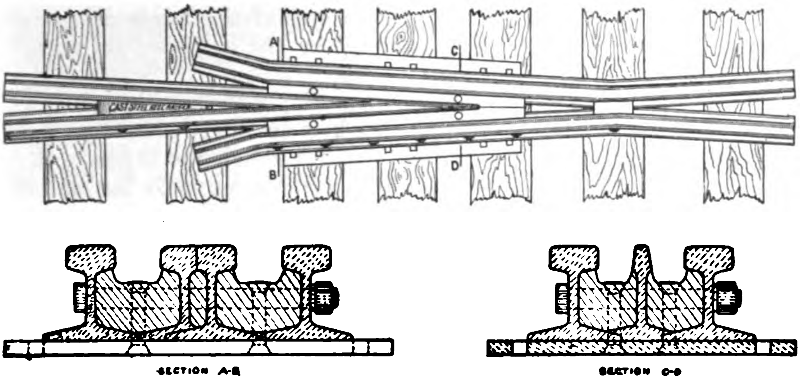


Fig. 76.—Combination Bolted-Plate Frog.

which are riveted to the point pieces each side; a U-bar is also placed in the throat. The arrangement is shown as Fig. 77. An advantage claimed is that a deeper channel is secured than could be had with ordinary filling blocks.

Rigid frogs of large angle are sometimes made with short pieces of double-headed wing or "easer rail" near to and opposite the tongue, so as to furnish a broader bearing surface for the wheel tread, and thus render cutting less severe. This double head is made by planing away the flange from one side of a short piece of rail and then bolting the piece to the wing rail. The space for a short distance between the two point pieces in rear of the tongue forms a place for the outside flange of badly worn wheel treads to spread the point pieces when running in the direction trailing the frog. To prevent this trouble the space is filled with a "heel block" or "heel raiser," as shown in Fig. 76. It usually consists of a short piece of rail planed to fit between the point pieces, so as to afford

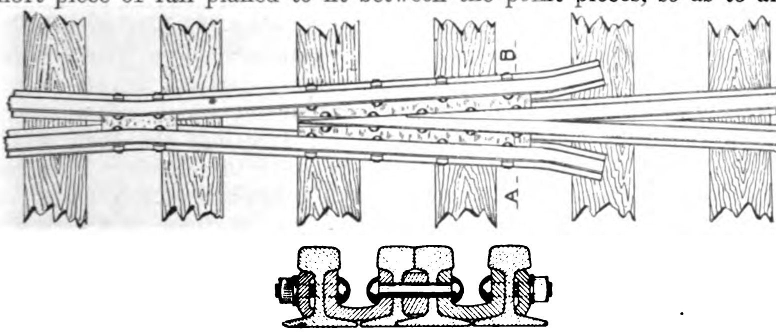


Fig. 77.—"U-Plate" Frog.

a bearing for the outer flange of guttered tires and carry it over without spreading apart the point pieces. The broad end of this piece of filler rail is sloped down so that an outside flange can mount it gradually. In some instances the short piece of rail planed down for the heel block is inverted, and in others a cast steel block extending far enough back to serve as a foot guard is used. In any case the "raiser" or "lifter" piece should extend back as far as the point where the combined width of block and rail head covers the reach of the engine tires. Heel blocks should be securely bolted through and through with the point pieces, as, being wedge shaped, the striking of "double flanges" tends to drive the block ahead and spread the point pieces apart. In some instances where trouble of this kind has occurred trackmen have taken the block out and thrown it away. The need of such a device is suggested by the fact that where it is not in service the inner top edges of the heads of the point pieces will usually be found chamfered off by the climbing action of the wheels.

Spring-Rail Frogs.—In an ordinary spring-rail frog the wing which takes the bearing of wheels on main track is movable, and, except when it is spread by the flange of a wheel passing through the turnout, it rests against the point pieces. With such a frog there is normally but one channel. As successive wheels pass between *D* and *H* (Fig. 78) the movable wing, or "spring rail," as it is called, is pushed aside by the flanges and returned to normal postion by the spring. As to the position of the spring which holds the movable wing against the point rails there are divers arrangements. A very common device is that shown in Fig. 78, consisting of a bolt *A-B* across the mouth of the frog, with a boxed spiral spring at either end. The objection to this arrangement is that the bolt or spring

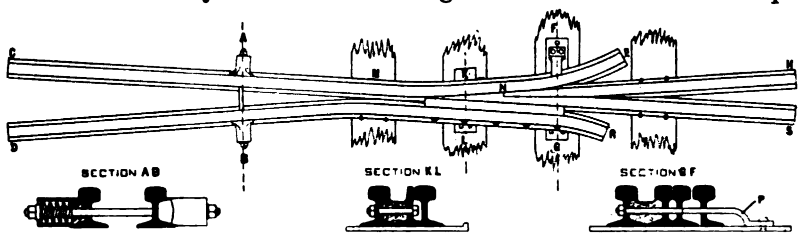
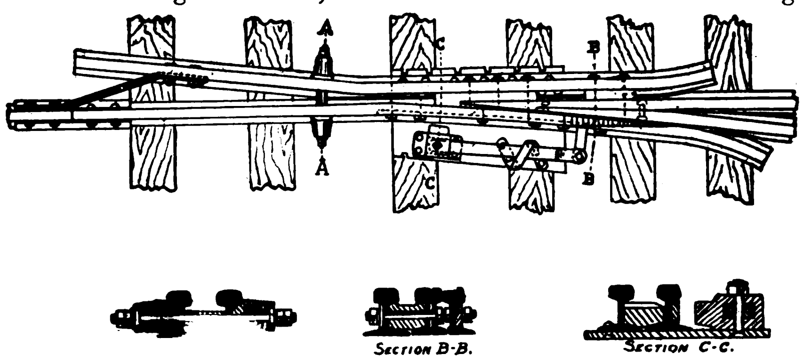


Fig. 78.—Ordinary Bolted Spring-Rail Frog.

is exposed at both sides of the rail to the chance of being cut by a derailed wheel. A safer arrangement in this respect is had by placing the springs in the position shown in Fig. 83, with the spring bolt through the tongue (Section *C-D*), but it stands open to the objection that only a slight creeping of the rail will cause the bolt to bind and render one or both springs inoperative or unable to return the spring rail to its normal position. In the mouth of the frog the spread of the rails gives the bolt more latitude of movement in a case of creeping, and it is not so liable to bind. Another arrangement which is considered safer against derailed wheels than the one first mentioned is that of using a boxed spring which acts against the movable wing somewhere between point of frog and the heel, with no bolt through the frog. Figures 85 and 86 show this device. It is found most frequently, but not exclusively, with hinge-rail spring frogs. One style of Weir frog has both arrangements—that is, there is a spring bolt across the mouth of the frog and a boxed or housed spring at the heel bend of the movable wing. Any rigid frog can be used with a switch turning either to the right or left, whereas the same spring-rail frog can be used only with switches turning in one direction; hence frogs of this type must be made rights or lefts, as there is demand for them. A frog or



g Devices for Spring-Rail Frogs.

switch is right or left according as it will turn a car to the right or left when entering the turnout.

The spring-rail frog is much more durable than the rigid frog, as it presents a continuous-bearing main-track rail, and does not therefore allow the wheel to drop in the channel after trailing the point and cut into the wing rail at the outer edge of the tread. Its life is generally conceded to be at least three times that of a rigid frog. Spring-rail frogs of various designs have to a large extent taken the place of rigid frogs for main-line service and are now very generally standard. For the successful operation of spring-rail frogs three devices are recognized as particularly essential; namely, an anti-creeping device, a holding-down device and a reinforcement for the spring rail. In the frog of ordinary type the spring rail *C E* (Fig. 78) is secured to the main-track rail only by a splice at the joint *C*. A connection between the splice and turnout leg at this end of the frog is sometimes made by bolting a heavy bar or strap between the two, as shown in Fig. 79. The bolt holes of this strap match with

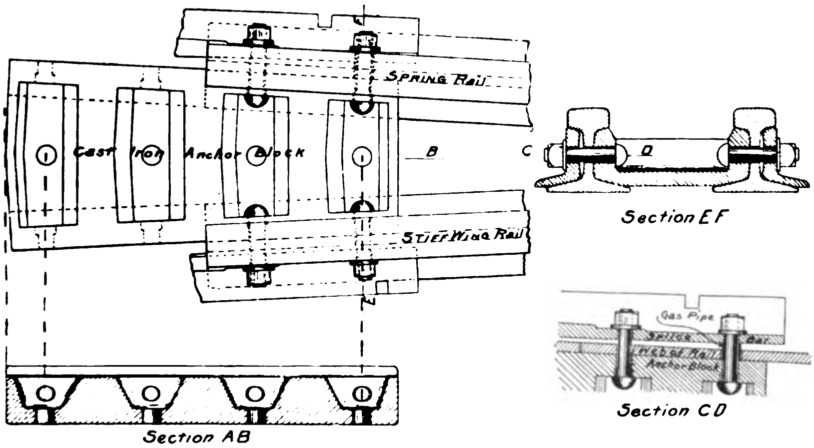


Fig. 80.—Cast Iron Anchor Block for Spring-Rail Frogs.

those in the splice, so that it is held by the heads of the ordinary track bolts. This connection holds the joint at the toe against being worked loose or spread by the action of the spring rail and allows of no creeping of that rail relatively to the fixed parts, which, if permitted to occur, would lock or bind some of the parts of the frog and restrain the freedom of action of the spring rail. Thus, for instance, creeping might cause the holding-down arms to bind so hard in their housings that the springs would not be able to bring the movable rail back against the point piece after being opened by passing wheels. There is also a danger element in unrestrained creeping, in that the binding action on the spring rail may be so intense that it will not spread for the wheels of empty freight cars trailing out of the turnout. In such cases cars have been known to climb the rail at the flare and go off the track.

Another anti-creeping arrangement is a cast iron anchor block bolted in between and through the two joints at the toe and spiked to the tie underneath. It is shown in Figs. 80 and 83. Another anti-creeping device is had by attaching the spring rail to one end of a parallel arm or link arrangement which is anchored to the frog plate, as shown in Fig. 81. One pattern of Weir spring frog designed for use in turnouts with Wharton switches has two links attached to the spring wing, one extending from its pivot toward the heel, as in Fig. 81, and the other extending from its pivot toward the toe, or in the opposite direction from that of the other. Owing to the unbroken rail at a Wharton switch the tendency of the main-track lead rail to creep in the facing direction is greater than is the case with a point switch, and the purpose of the double link arrangement is to afford a stronger resisting device and, also, by pivoting each link to stand at a small angle with the spring wing (that is, out of parallel with it), to always force the spring wing against the point pieces, no matter in what direction creeping takes place. In Fig. 82 is shown an anti-creeping device consisting of a link carried between two strong lugs in the mouth of the frog, one projecting from the spring rail and the other from the turnout leg.

In order to hold down the free end of the spring rail while wheels are passing a low joint at the toe, or prevent it from being raised by dirt or snow, or from being torn up by dragging brake gear, several devices are in use. That shown in Figs. 78 and 83 is common. It consists of a flat bar bolted to a base plate and passing through a slot in the web of the spring rail, beyond which it is attached to a bolt or is shouldered and drawn out into a bolt which passes through the rigid rails. Another device consists of a lug or plunger bolted to the web of the spring rail, and working into a holding-down cuff or guide box secured to the base plate, as shown in Figs. 81 and 82. This cuff permits some longitudinal play of the spring rail but no appreciable vertical play. Another form

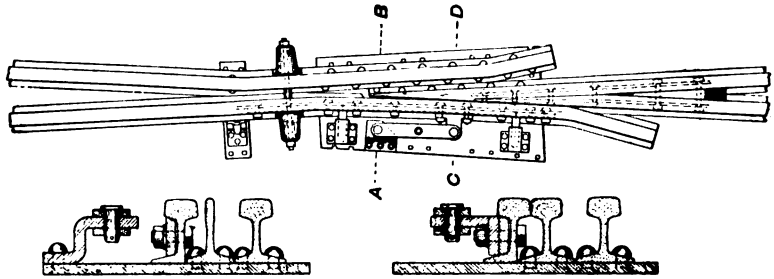


Fig. 81.—Link Anti-Creeping Device for Spring-Rail Frog.

of holding-down device consists of a narrow, flat plate riveted to the base of the spring rail and extended under the rigid rails; and still another consists of a heavy "monkey tail" strap bolted to the web of the spring rail at the end and twisted downward to extend under the rigid rails. This form of holding-down device for a plate frog is bolted to the web of the spring rail at the side, somewhere near the end, and is then bent around the edge of the plate to pass underneath. Figure 79 shows a combined holding-down and anti-creeping device which explains itself. The anti-creeping attachment to the splice at the toe is obviously not used with this frog, being shown in this figure only for the purpose of illustration. When two holding-down devices are used they are ordinarily placed opposite the point and heel respectively; when only one, it is placed near the heel. The spring rail is prevented from being opened too far by stops or rail braces secured to the base plate or by arranging the holding-down devices to answer as stops; these limit its movement to the width of the proper channel or flangeway. They ought to be placed opposite throat, point, and heel of wing rail and be so adjusted that they act together, all opposing any abnormal movement of the spring rail at the same time. Where tie plates are riveted to the base of the frog the ends of the same are sometimes split and a strip of metal half as wide as the plate is bent up at the proper distance from the spring rail to form a stop, as in Fig. 82 A. In some instances where enough stops have not been provided in the construction of the frog, ordinary rail braces have been used.

The flange of the spring rail, opposite the point pieces, must necessarily be cut away, so as to allow its head to rest against the head of the point piece. This trimming of the flange weakens the spring rail, and, for a long time a valid objection to the use of the spring-rail frog was that when the spring rail broke there was nothing to hold the broken piece in place, whereas in a bolted or plate-riveted rigid frog the broken piece is held fast. To guard against the probability of such danger all spring rail frogs of modern pattern have the spring rail reinforced by a heavy wrought iron strap or equivalent device bolted or riveted to the web. This strap is usually ¾ in. thick and is placed on the outside of the rail, but an additional strap about ⅜ in. thick is sometimes secured to the inside, thus reinforcing both sides of the web. The spring rail of the standard frog of the Chicago & Western Indiana R. R. is reinforced with a piece

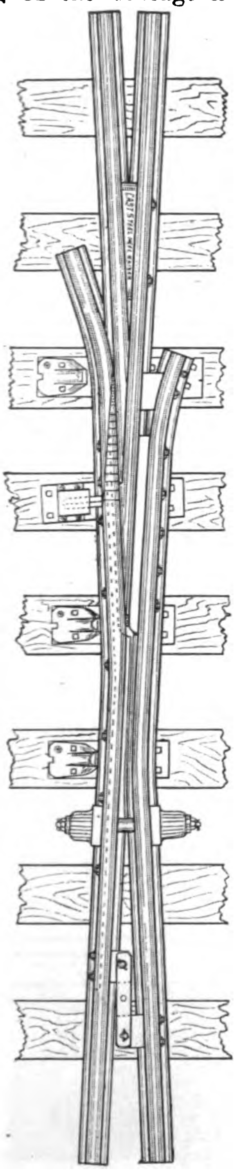


Fig. 82.—Frog with Link Anti-Creeping Attachment in the Mouth.

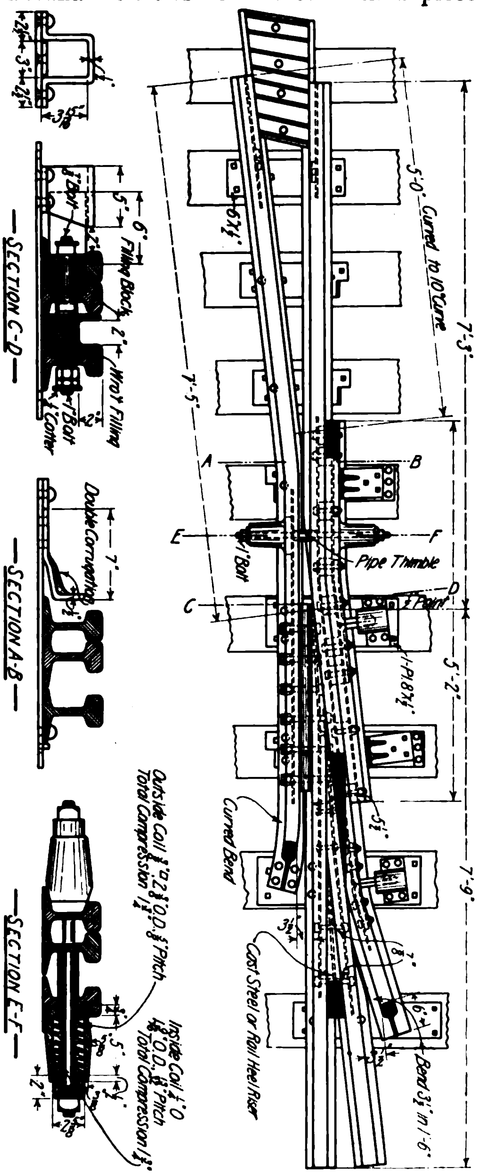


Fig. 82 A.—Standard Spring-Rail Frog, Chicago & Western Indiana R. R.

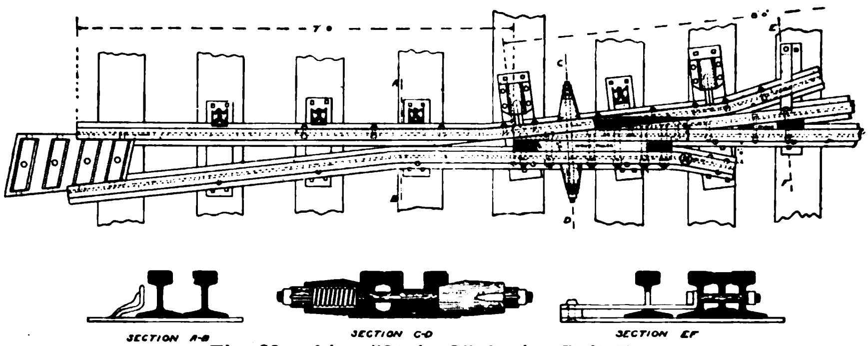


Fig. 83.—Ajax "Style G" Spring-Rail Frog.

of rail 5 ft. 2 ins. long planed to shape and bolted on with the heads touching and a filling piece between the webs. The middle of the reinforcing rail comes about opposite the point of frog. To prevent dragging parts from catching, the heel of the spring rail is cut off at a slope of 40 deg. with the horizontal.

The spring rail does not usually rest against the tongue (Figs. 79 and 81), but is flared out over a length of about 8 ins., so as to allow the wheel flange to pass the point, when entering the turnout, without crowding the spring rail over (at least to its full extent). This arrangement is calculated to relieve the guard rail opposite the frog of some strain. The loose end of the spring rail should be flared out gradually, so as to avoid sharp blows when it is set over by trailing wheels and prevent sharp wheel flanges from cutting into or mounting it. The usual flare, measured when the spring rail is closed against the point piece, is $3\frac{1}{2}$ to 4 ins., and the length of flare, 17 to 20 ins.; with the rigid wing the flare and length of flare are usually the same as in rigid frogs. The flare for this end guard should not begin until more of the side point piece than any wheel tread can cover has been lapped by the closely-fitting portion of the spring rail. Ordinarily this specification requires that the spring rail shall extend farther toward the heel than the fixed one, and it very much reduces the risk that the spring rail will be caught and opened by the outer edge of the tread of deeply worn wheels trailing the frog on main track. Nevertheless it does not alleviate the punishment of the spring rail by the cutting action of worn wheel treads. To provide against trouble of this kind it is necessary to channel or groove the head of the spring rail (*B-B,* Fig. 79) parallel to the main-

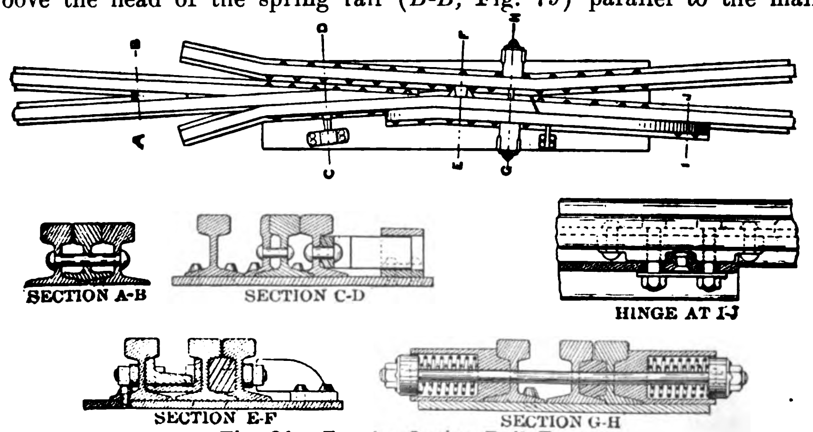


Fig. 84.—Eureka Spring-Rail Frog.

track gage line, and to such a width as will cover the reach of the outer flange of any badly worn tread. Another arrangement is where the spring rail is made to fall or drop away gradually ¼ or ⅜ in., say from the point *N*, Fig. 78. This inclination is accomplished by reducing the thickness of the plate under that part the proper amount, thus placing the endangered portion of the rail out of reach. An arrangement in vogue with the New York Central & Hudson River R. R. is to plane down the head of the spring rail on a slope from the point where the guttered tire reaches over the point piece to the free end of the spring rail, where the

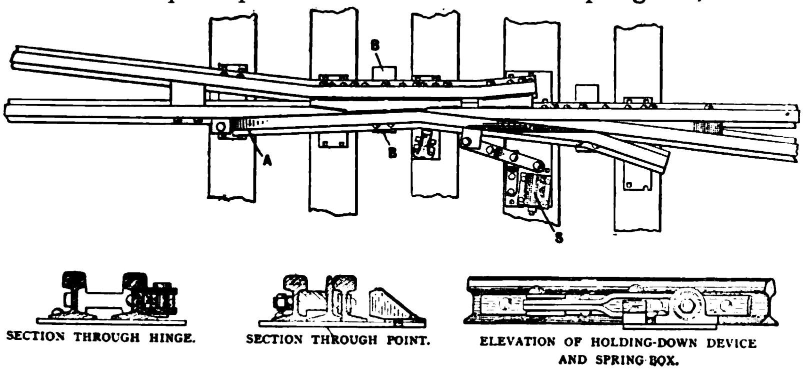


Fig. 85.—Frog with Hinged Spring Rail.

head retains about half its regular depth. The foregoing four features of design, namely the anti-creeping device, the holding-down attachment, the reinforcement of the spring rail and the grooving of the spring rail for worn wheels, should all receive careful attention in the selection of spring-rail frogs.

To avoid the necessity for special devices to prevent disturbance to the spring rail by creeping of the track, and to render the spring rail less dangerous in case of breakage, several designs of frogs have been brought out wherein a short spring rail is hinged either to a rigid leg or to the base plate opposite the mouth, or to the side point rail at the heel, thus removing it from the line of stress. All four ends of the frog are fixed, as in a rigid frog. In the Eureka frog (Fig. 84) the spring rail makes a miter joint with a fixed leg in the throat and is bolted to a piece of reinforcement rail which breaks this joint and is hinged at *I-J*, thus affording a double running rail. In the Weir frog of this type (Fig. 85) the spring rail is outside the gage line of the main running rail and is bent so as to

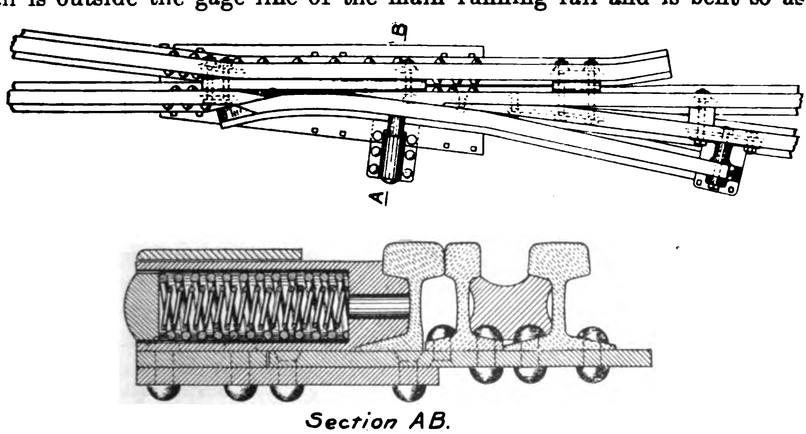


Fig. 86.—Vaughan Spring-Rail Frog.

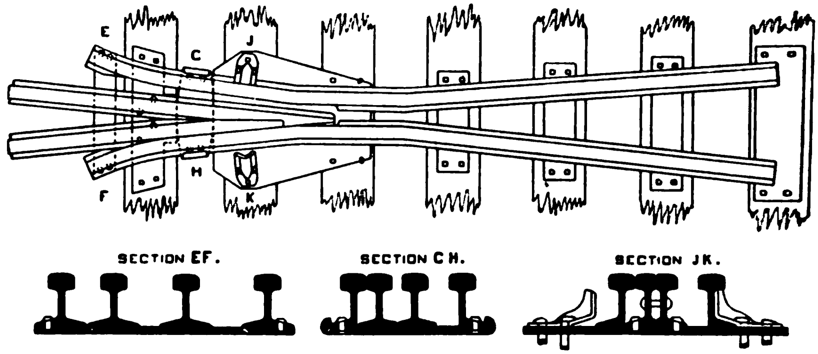


Fig. 87.—Wood Sliding-Rail Frog, Pennsylvania R. R.

project somewhat within the opening between the point piece and a rigid piece in the main running rail. It is hinged at *A*, and held up to the point piece by a spring *S*, acting reversely to the usual direction on the shorter arm of a pivoted lever, which effects a reduction in the compression of the spring. One of the holding-down devices is shown at *B* and consists simply in a plate riveted to the base of the spring rail and projecting under the rigid portion of the frog. There is a similar device at the flare of the spring rail. In another style of Weir frog the holding-down plate is of similar design and works through a guide riveted to the under side of the main point piece. The filling between throat and point is of steel and arranged to hold up and guide the wheel flange, even though the spring rail was broken or entirely removed. The Vaughan frog, shown in Fig. 86, is quite similar to that just described. The spring rail is hinged at the heel, however, instead of at the mouth, and is not bent so sharply

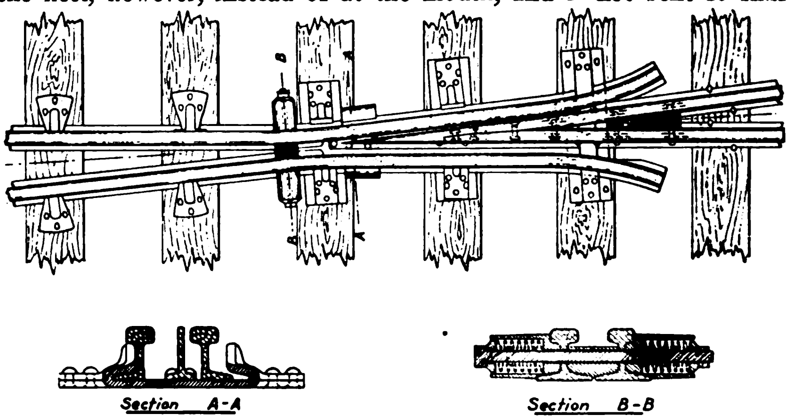


Fig. 88.—Vaughan Sliding Spring-Rail Frog.

opposite the point of tongue. The filling block is arranged to carry the wheels, in case of accident to the spring rail, as in the other case, and it has a rib fitting under the head of the spring rail.

Promiscuous Designs.—A good deal of attention has been devoted to frogs of special design for yards, or for the junction of two tracks both of which carry heavy traffic, the object in view being a continuous-bearing rail for trains moving over the frog on either track—main or turnout. The Wood frog, shown in Fig. 87, is one of the oldest of this type. The point pieces are made rigid or fast to the plate. The wing rails are rigidly attached to each other, but not to the plate, so that either wing rail may rest against the point rails, according as it is moved to position by the crowding of the last wheel flange which passed against the opposite wing rail. There is no spring and, the wing rails being held rigidly together by base clamps at *C-H* and *E-F*, the point rails thus act as a stop for them. This frog is intended for use in yards, where speed is slow and the turn-out side of the frog is more frequently used than is the case with most frogs on main line. It was designed by Mr. Joseph Wood, an engineer of the Pennsylvania R. R., and has been used for many years on the United Railroads of New Jersey division of that road. The design is open to the objection that the automatic setting of the wing rails, when not in place for a wheel approaching in the facing direction, takes place with the weight of the wheel on one of the wings. The movement of the wings under load must therefore be attended with much friction. Moreover, should a bolt, a nut, or any piece of iron drop from a passing train into one of the channels of the frog, the wings would be rendered immovable and serious consequences might follow, to both the frog and the train. To accomplish the same purpose, namely, to produce a frog with double spring rails which do not open and close at the passage of every wheel or truck over the frog, there is a design known as the Vaughan sliding spring-rail frog (Fig. 88), in which the two movable wings, instead of being rigidly attached to each other, are spring connected in the usual manner. These spring rails are separated by a spacing block on the spring bolt a sufficient

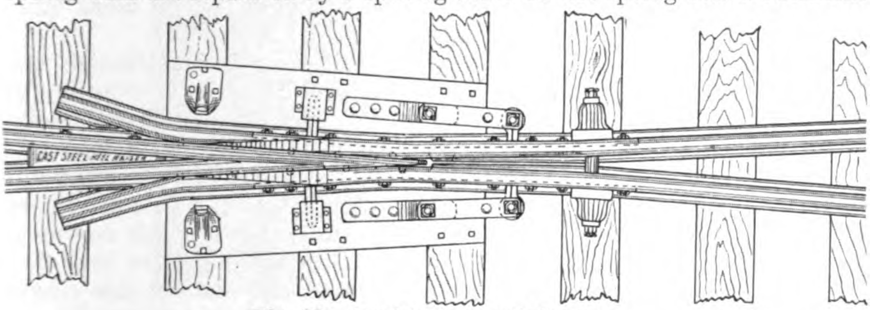


Fig. 89.—Double Spring-Rail Frog.

distance to maintain an open flangeway in the track in use, the flangeway in the unused side remaining closed. In case wheels passing over the frog in the facing direction run through the closed flangeway, the closed wing is forced open, compressing the spring, as in the ordinary action of spring-rail frogs, the movement of the other wing rail follows, as soon as it is released from load, and the frog then remains set for that route. When the frog is set by trailing wheels both wing rails are moved to place simultaneously, without bringing the spring into action. Both wings are backed by proper stops, and should one of them be blocked by any object falling between it and the tongue, the other wing, being retained only by springs, is allowed to move; hence the objectionable feature consequent upon attaching both sliding wing rails rigidly together is removed. The Douglass double spring-rail frog is a plate frog of substantially the same construction operating in the same manner.

Of double spring-rail frogs which open and close at every passage of a wheel or truck there are a few examples in service. The frog shown as Fig. 89 is of substantial construction, with heavy link anti-creeping attachments on both wings, and either wing acts independently of the other. The Eureka double spring-rail frog operates on the same principle, being of the same design as that illustrated by Fig. 84, except that the movable wing rail is duplicated on the other side of the point. A double spring-rail frog (Fig. 90) in use on the Michigan Central R. R., designed by Mr. O. F. Jordan, formerly roadmaster with that road, has wing rails rigidly secured at both ends. At the toe the wings are spliced to the lead rails in the ordinary manner, while at the other end of the frog they extend 2½ ft. past the heel of the point pieces and are securely bolted to the fixed main and turnout rails through filler blocks 8 ins. long. The flare at these blocks is the usual 4 ins., and the wing rails, which are 19 ft. long, are bent to rest normally against the point pieces by the action of their own spring. Ordinarily the elasticity of the rails themselves is sufficient to hold them to place, but to provide against accident they are reinforced at the mouth by a spring bolt. The pressure of the wheel flanges opens the wing and the width of flangeway is limited by stops

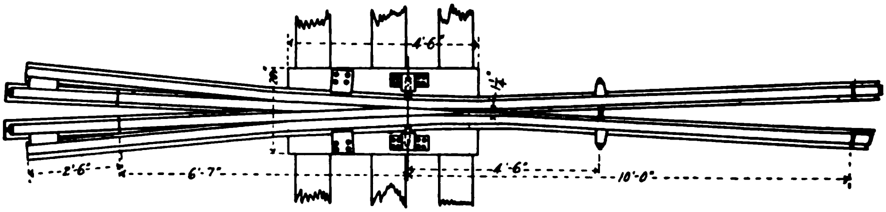


Fig. 90—Jordan Double Spring-Rail Frog, Michigan Central R. R.

secured to the base plate to which the point pieces are riveted. Vertical movement of the wing rails is restricted by hold-downs of the usual form. This frog is used only in yard tracks.

None of the foregoing double spring-rail frogs is in extensive use. They are rather expensive for general yard service, and the propriety of placing at the end of double track, or at the junction of two main tracks, where high speed is made, any frog with movable parts to be automatically set by the train is certainly questionable. As a matter of fact spring-rail frogs of any description are used but little in yards. In such places the speed is necessarily slow and the spring rail is not so much needed as it is in main line, and then there is also the forcible objection that they cannot be blocked as effectually as rigid frogs, and are for this reason a greater source of danger to brakemen in getting their feet caught. It is also proper to remark that spring-rail frogs are not considered as safe in the outside rail of curves as are rigid frogs, for the reason that the yielding wing throws all the duty of guiding the wheels between toe and point upon the guard rail; with a rigid frog this duty is imposed only while the wheels are passing between throat and point.

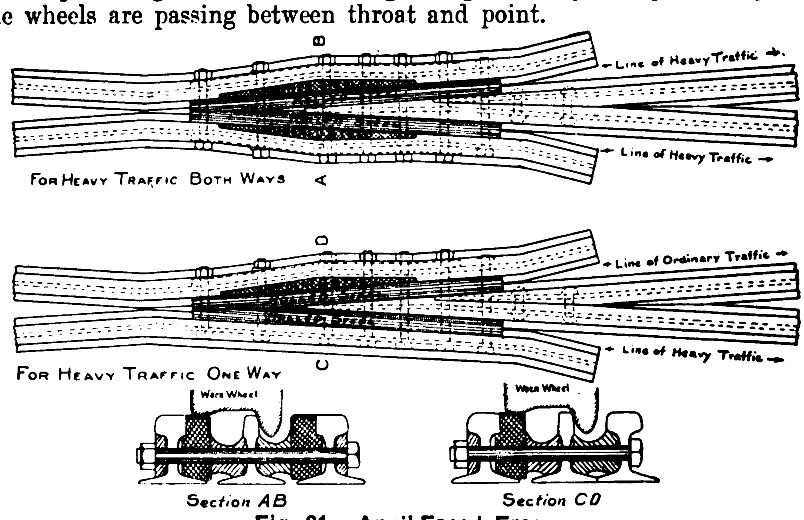


Fig. 91.—Anvil-Faced Frog.

For service under heavy traffic there is a rigid frog with hardened steel parts to take the bearing opposite the point, where the wear is usually most rapid. This frog, known as the "Anvil-Faced" frog, is in use on a number of roads, the Pennsylvania, the Southern and the Lake Shore and Michigan Southern, among others, and is illustrated by Fig. 91. The upper engraving shows the design for heavy traffic over both tracks, while the lower design is intended for heavy traffic on only one track through the frog. The frog is constructed in the ordinary manner, the space for the hardened portion being provided for by bending the wing rail around it. A frog with wearing parts of manganese steel is described in §214.

On some of the English railways trial has been made of frogs with hot-pressed flangeways. In the Tyler & Ellis frog (made by the Tyler & Ellis Mfg. Co. Ltd., at Peterboro, Northamptonshire, England) the main rail through the frog is continuous, the flangeway for the turnout being formed by heating the rail and pressing it into the head by hydraulic machinery. The metal displaced is not cut away, being forced downward to strengthen the web. Some of these frogs used on the Great Northern Ry. (England) are reported officially to have given fairly satisfactory results. They are in use on some of the railways of South

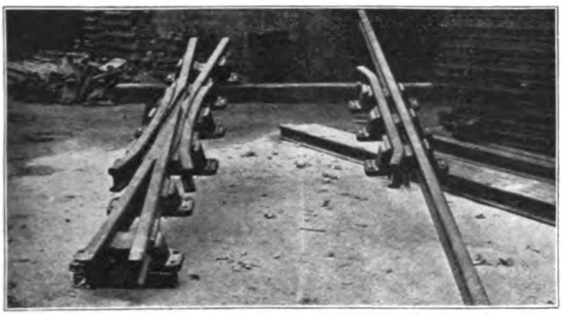


Fig. 91 A.—Split Twin-Rail Frog, Midland Ry.

America, and they have been tried experimentally on the Pennsylvania R. R., in West Philadelphia. Another method of manufacturing frogs, designed by the well-known railway engineer, Mr. Price Williams, in co-operation with Mr. E. P. Martin, equally well known as an iron and steel manufacturer, is worked by the Railway Switch & Crossing Co., Ltd., 15 Victoria St., Westminster, London, England. The frogs are known as "split twin-rail crossings," the four legs being formed by splitting up the ends of a rail rolled double the usual width, by sawing, and opening out the two halves of the same to form the frog angle. Figure 91 A shows an ordinary frog made by this method of rail-splitting. After opening out the split ends of the rail, grooves are planed out for the flangeways, and wing rails bent to proper shape are then clamped on. The four legs of the frog and the tongue are therefore one solid piece, and there can be no "ducking" of the point under traffic. As will be noticed, both the frog and guard rail shown are assembled by means of cast chairs, with tightening wedges driven against the web of the rail. Double-pointed crossing frogs are made by the same process (See Railway and Engineering Review, Feb. 23, 1901). The Midland Ry. (England) is one of the roads on which these frogs are in service.

Some Features of Frog Design.—The usual practice in making frogs has been to cut off the legs, at toe and heel, evenly. This arrangement brings the two splices at each end of the frog directly opposite, and unless the point pieces in frogs of small angle are of unusual length there is not room enough inside the rail ends for two angle bars, to splice the joints, so that fish plates must be used or else the bottom leg of one of the angle bars must be cut away. The same kind of interference occurs at the toe of short rigid frogs. This trouble may be avoided by making one point piece and one wing rail each longer than its mate by the length of a splice bar, as in Fig. 92. I have seen this plan carried out in practice, with good results in more ways than that just stated. To further discuss the advantages of the arrangement it need only be said that the principle of breaking joints is of universal application in engineering practice. Nothing lies in the way of standardizing frogs designed on this plan. If the angle of the frog was computed with the idea of laying the frog in one of two ways relatively to two 30-ft. rails in main track, as heretofore discussed, a piece of rail of fixed length, less than 30 ft. (or whatever standard rail length) by the amount one wing rail is longer than the other, should go with the frog to be put in main track or turnout, according as the frog is to be used as left or right. Since spring-rail frogs can be used but one way, the rigid or turnout leg should always be cut off enough longer (about 2 ins.) than the main or movable leg to make up for the increased length of the turnout lead over the main-track lead, thus making it

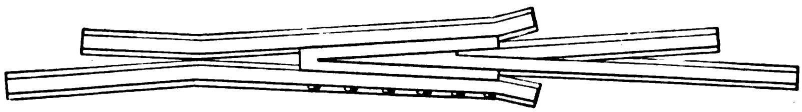


Fig. 92.—Frog with Unequal Legs.

possible to square the joints at the headblock or heel of switch without extra cutting or by using a short piece of rail ("dutchman"). The frogs shown as Figs. 82A and 83 are made in this manner, and the practice is now standard with a number of roads. With spring-rail frogs, also, the turnout side should be curved to fit the lead corresponding to the number or angle, thus avoiding the necessity for a short stretch of straight track in the turnout at the frog. If the leg of the frog is long enough that portion can be sprung to the curve, but it might just as well be curved when the frog is made. An example of this practice of curving the fixed wing of a spring-rail frog is shown in Fig. 82A.

A good deal might be said on the question of the proper length of frogs, particularly rigid frogs. As the wear of rigid frogs under heavy traffic is rapid, it is an old and familiar text that it is a waste of material to make the legs longer than is required to obtain the necessary spread for splicing; hence 9 or 10 ft. has been the customary length of rigid frogs. It should be understood, however, that the length of the frog has much to do with the conditions of wear. When the wing of a frog not longer than 10 ft. gets loose there is then in the track a pretty short piece of rail to flop up at the passage of every wheel over the toe. A frog made of long pieces is not so soon loosened under the jar of the traffic as is one made of short pieces. Rigid frogs should be at least 12 ft. long and a length of 15 ft. is much better. The Chicago, Rock Island & Pacific Ry. uses in main track rigid frogs of plate-riveted pattern 15 ft. long. The Chicago & Northwestern Ry. has standard rigid frogs 17 ft. and 20 ft. 1 in. long (Fig. 157A). The worn parts of a 15-ft. rigid frog will still make a 10-ft. frog for use in yards or side-tracks. The most frequent length of spring-rail frogs, up to No. 10, is 15 ft. The length of spring-rail frogs of higher number is usually greater. With the Pennsylvania R. R. the standard toe-to-heel lengths corresponding to No. 10, No. 11 and No. 13 frogs are 15 ft., 18 ft. and 20 ft., respectively.

The standard width of channel for frogs is $1\frac{3}{4}$ ins. If proper attention be paid to the gage of the track and of the guard rail, this width allows plenty of room for wheel flanges. One object in restricting the width of channel or flangeway to the actual requirements is to so constrain the wheel that its tread reaches as far as possible over the wing on the opposite side of the tongue, thereby increasing the bearing surface. As between channels $1\frac{3}{4}$ ins. wide and $1\frac{7}{8}$ ins. wide, on a No. 9 frog, say, the wheel tread is constrained to follow the wing rail in the former case $1\frac{1}{8}$ ins. farther than might occur in the latter case, and the bearing for some little distance is $\frac{1}{8}$ in. wider. Increase in width of channel or flangeway increases the length and width of the open spaces behind the gage lines, between the point of tongue and the throat, on both sides of rigid frogs and on the turnout side of spring-rail frogs. A recognition of this principle is shown in one of the designs of the Elliot company, known as the "Main Line" frog, in which the flangeway for the turnout is considerably narrower than the one for main track, thus affording all possible bearing for the wheel tread in the vicinity of the point. To refer again to the matter of flaring the guard ends of the wing rails, it may be said that the method of making the flare by beveling off the side of the rail head is rather too abrupt, and not as satisfactory as that of bending the end of the rail to make the flare.

Frogs should be designed and constructed to standard specifications, so that like parts of frogs of the same number and pattern will be interchangeable. Before specifications are finally adopted, however, they should be put to the test of making a frog and be submitted for the criticism of the frog maker. In this way slight modifications may sometimes be suggested which will improve the design. It is well to have a care about being too rigorous with the minor and unimportant details. A case in point comes to mind where the engineers of a certain road had spent a good deal of time preparing an elaborate set of specifications, which covered all such minute details as the exact location of every bolt and rivet, and other folderols, and before testing their correctness they were printed in pamphlet form. When the manufacturer came to make the frogs he found bolts which interfered with others and with hold-downs, and the workmen found other incongruities. It is not always important that bolts and rivets should come in just such and such places, but it is important that all frogs of the same designation should be made alike. To this intent the specifications may point out the dimensions wanted and should require a certain uniformity of parts and interchangeability. Of course it is necessary that the drilling of the main bolt holes in different frogs should correspond. Details not concerned in these requirements may then be left to the frog maker. In a general way the same principles of design apply to the specifications for split switches. Table XII is submitted as an

Table XII.—Standard Dimensions for Spring-Rail Frogs of Various Angles.

FROG No.	LONG POINT	SHORT POINT	½" POINT TO TOE	FIXED WING RAIL	MOVABLE WING RAIL	TOTAL LENGTH	HOLES IN POINT
4	8'-6"	7'-11"	6'-6"	10'-7"	9'-10"	15'-0"	6
5	8'-6"	7'-11"	6'-6"	10'-7"	10'-3"	15'-0"	6
6	8'-6"	7'-7"	6'-6"	10'-7"	10'-10"	15'-0"	6
7	8'-6"	7'-6"	6'-6"	10'-7"	11'-3"	15'-0"	6
8	8'-6"	7'-5"	6'-6"	10'-7"	11'-8"	15'-0"	6
9	8'-6"	7'-1"	6'-6"	11'-1"	12'-1"	15'-0"	7
10	8'-6"	7'-0"	6'-6"	11'-1"	12'-8"	15'-0"	7
11	10'-0"	8'-6"	8'-0"	12'-7"	14'-3"	18'-0"	7
12	10'-0"	8'-2"	8'-0"	12'-7"	14'-8"	18'-0"	7
13	12'-0"	10'-0"	8'-0"	13'-0"	15'-1"	20'-0"	8
14	12'-0"	10'-0"	8'-0"	13'-0"	15'-6"	20'-0"	8
15	12'-0"	9'-8"	8'-0"	13'-0"	16'-2"	20'-0"	8

example of the dimension features of a set of specifications for the spring-rail frogs of a certain large railway system. These specifications cover frogs made from 60-lb., 70-lb., 85-lb. and 100-lb. rails.

The advantage of interchangeable parts is that spare pieces may be kept on hand for the repair of broken ones or ordered to replace worn parts. Thus, the point pieces of a rigid frog will outlast the first set of wings, and to get all the available wear out of these frogs the worn wings may be exchanged for new ones, or the worn wing of a frog in a turnout to the right may be exchanged for the unworn wing of a frog in a turnout to the left. With bolted and clamped frogs such exchanges may be made in the track, but plate-riveted frogs require to be sent to the shop. In the former case it is usual to have a spare frog on hand to put down in the place of one of them between which an exchange of wings is made, but where such is not the case and wings are to be exchanged at a distance, the switch may be spiked at some favorable interval between trains and a short piece of rail spliced in temporarily to take the place of the frog while the transfer is being made. When repairing frogs by changing the wings it is sometimes necessary to shim up the worn point. Interchangeable wings for crossing frogs are referred to in connection with the subject of crossings.

As frogs must undergo unusual service the material used in making them should be first class; nevertheless they are frequently made from rails of second quality. Rails not quite up to standard size in width or depth of head or in total hight of section should obviously not be selected for frog material; likewise rails with such defects in head, web or base as might affect the strength.

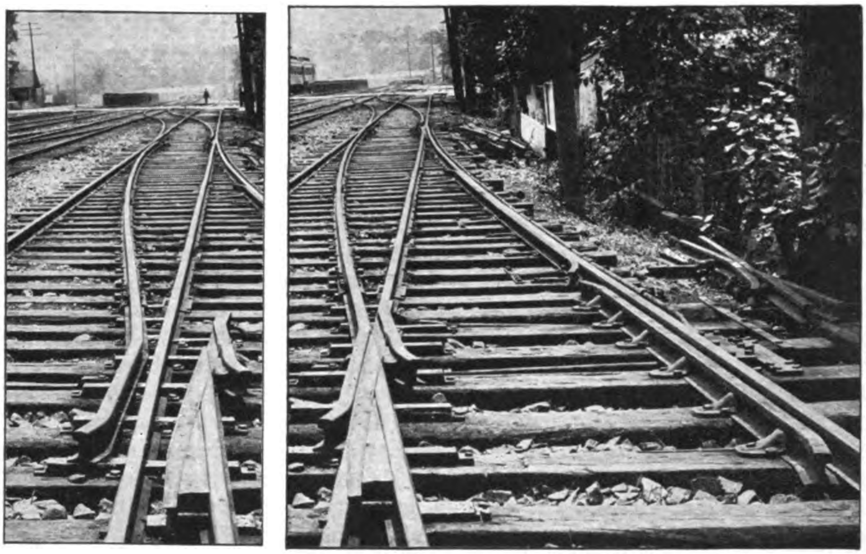
Laying Frogs.—With 1¾-in. flangeways through the frog there will be no trouble from wheel flanges striking the wing rails, providing the frog is laid to exact gage. Some trackmen are always apprehensive of spiking a frog to gage, even on straight track, but there is no necessity for fear in this regard; indeed if there be any cause for anxiety it should be rather for not laying the frog to gage. The nearer the frog is spiked to gage, the less severe will be the blows of the wheel flanges on the wings. If the wing is struck heavily by wheel flanges the spikes holding the frog are usually spread, and accordingly some will brace the frog wings with rail braces; but this it not the proper thing to do. When the wings are being severely used it indicates that the frog is out of gage, and the proper remedy is simply to put it in gage. On this point there are some inconsistencies of practice. The rules of some American railroads require that the gage of both tracks within the limits of the turnout (point of switch to heel of frog) shall be ¼ or ½ in. wider than standard, and that outside of these limits the gage shall be narrowed to standard in a distance of 30 ft. in each direction. In tracks where there are several switches in succession or close together, as in the ladder of a yard, the widening of the gage is maintained throughout, or past all of the switches and frogs. On the other hand, it is extensively the practice on English and European roads to lay frogs and switches and the track intervening ¼ in. tight for gage, the idea being to prevent lateral play of the wheels and steady the motion of the trains past the turnouts.

The way to lay a frog is to first splice it to the main-track rails at toe and heel, spike the heel to gage for main track, and then do the same at the toe; then spike it to gage at a point about 6 ins. back of the point of tongue and drive the remaining spikes straight down without using the gage. A clamped or bolted frog spiked only at the heel and toe can usually be sprung a little at the point, in case it is not exactly straight;

or, if the frog is long enough, it may be sprung to an easy curve, if desired; but with a plate frog or any short frog made of rails of heavy section this cannot be done. In laying a plate frog it is not necessary to adz down the switch ties to make room for the plate, but let the plate rest on the tops of the ties; then when spiking the turnout rail opposite the frog, spring the ties up to it. A frog when first put in is all the better for being the thickness of the frog-plate high. In laying frogs care should be taken to leave the proper allowance for expansion at the joints at each end of the frog and for several joints in the adjoining rails. The angle bars should then be slot spiked at all these joints, so as to hold, as well as may be, against creeping. As the frog forms part of two tracks it should be in line with the turnout lead and the side-track rail beyond the frog, as well as with the main-track rail, but where the rails creep badly it is difficult to maintain this condition at all times; hence the necessity for frequent readjustment. The ties under the spring rail, particularly, should be evenly surfaced, so that the rail will be evenly supported and slide evenly on its plates.

The question of widening the gage on curves, already discussed, has to do also with frogs. A frog on the inside of a curve gets the worse for widening the gage, and there is no remedy, for the wheel flanges will continually be pounding the inside wing rail and breaking the frog bolts or loosening rivets or some other parts. The cause is clear. A reference to the M. C. B. standard frog and wheel gage (Fig. 96) will show that when standard-gage wheels are running on standard-gage curve and the flange of the outer wheel is crowding the rail, the back of flange of the inner wheel will reach over just 1¾ ins. from the gage side of its rail; hence it cannot strike hard against the inside wing rail of any frog spiked to gage, unless the flange of the outer wheel be badly worn. If, however, the gage of the track at this point be widened, one of several things must happen: either by the amount the gage is widened, by just so much must the channel of the frog be made wider than standard; or by just so much must both wheels be jogged over by the wing rail; or by just so much must the frog be jogged over under the wheels, unless the wing is loosened or the bolts broken; or else the sudden jar against the inside wheel must spring the car axle. The last named effect must at least subject the axle to much strain. It would certainly be interesting to know just what proportion of broken car axles is due either to improper gage at such points in the track or to improper gaging of the wheels. Of course, it is not usual to find a frog on the inside of a heavy curve; but suppose the gage is widened ½ in. and there is a frog on the inside of the curve. Then, unless the channel of the frog be widened to 2¼ ins., the front pair of wheels of every car truck passing that frog will get a jog sidewise, which in turn must jolt the car. Neither are conditions much more favorable to frogs on the outside of curves. Bolts in bolted frogs will be broken notwithstanding the widening of the opposite guard rail flangeway, because the rear wheels in each truck will seek the inner side of the curve, and if the gage at the frog be widened, such wheels will run that amount nearer the inside rail of the curve and strike against the wing rail of the frog. Such effects must certainly be telling upon rolling stock, and the time will come, no doubt, when more railway men will be brought to a realization of the fact that standard-gage track means standard-gage curve. The evil effects of widening the gage of track on curves have long been seen. Indeed, in years past it has been the practice of some roads to tighten the gage ¼ in. at frogs on the inside of curves, so as to provide against blows to the wing rail by wheels with worn flanges.

Effect of Guttered Tires.—The life of frogs of any type depends to no inconsiderable extent upon the vigilance of the mechanical department in maintaining the locomotive tires in good condition. The manner in which damage may occur from deeply worn wheel treads has already been pointed out in connection with features of frog design intended to provide against the same. No frog is well designed without a heel raiser, and in spring-rail frogs the grooving of the movable wing is an essential, but the question then arises as to how deeply this wear of the tires may be permitted to go before these devices will fail to give the desired protection. The heel raiser protects the frog against spreading of the point pieces by the false flanges of guttered tires, but it does not protect it against heavy blows from the same or prevent the wearing down of the side point. Abnormal wear to the wings of rigid frogs caused by badly worn tires cannot be prevented. For such reasons it is usual to set a limit upon the allowable depth of rut in locomotive tires; and this limit is quite liable to be



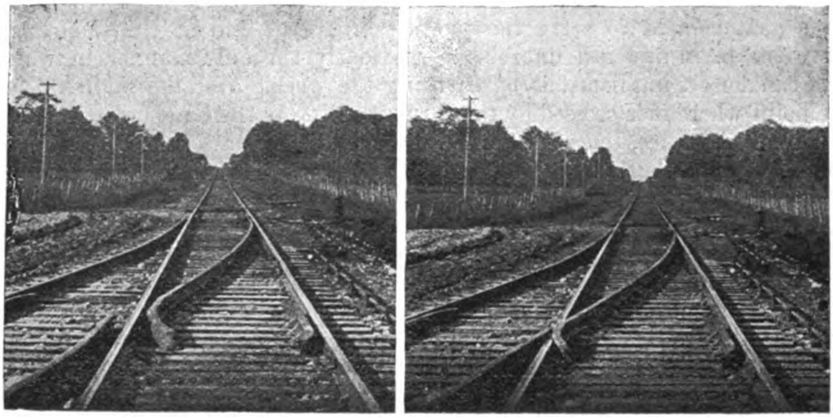
Set for Main Line. Set for Siding.

Fig. 93.—The Price Frog.

a compromise of the views of the track and motive-power departments, for the trouble and expense of frequently taking locomotives into the shops and turning down the tires is considerable. In 1891 the New England Roadmasters' Association recommended $^3/_{16}$ in., and in 1895 the Roadmasters' Association of America recommended $\frac{1}{4}$ in., as this limit. As to standard rules on this matter various railways seem to stand about evenly divided for $\frac{1}{4}$ in. and $\frac{3}{8}$ in. as the limit, but unless the roadmasters are watchful even the higher limit is liable to be exceeded in service. Some railways place the limit at $\frac{3}{8}$ in. for freight engines and at $^5/_{16}$ in. for passenger engines, but both are too high. The limit for passenger engines should not exceed $^3/_{16}$ in., and for freight engines the limit should not exceed $\frac{1}{4}$ in. in road service and $^5/_{16}$ in. in yard service. Tire-dressing brake shoes are helpful in maintaining tires in good condition. It is the business of roadmasters to report engine tires found worn deeper than the limit in force, and for the purpose of testing the depth of rut a pocket templet is convenient. The effect of hollow-worn tires on the stock rail of split switches, just in rear of the point where the planing of the point rail runs out, is about the same as on frogs and is again referred to.

Continuous-Rail Frogs.—Many attempts have been made to devise some arrangement to serve the purpose of a frog and at the same time leave the main-line rail unbroken. Obviously the only manner in which this can be accomplished is by carrying the wheels over the main rail at the point where it is crossed by the turnout rail. As there are a few frogs of this kind in service, some account of the same is proper. The Price frog, designed by Mr. C. B. Price, formerly division superintendent of the Allegheny Valley Ry., has been used on that road and on the Pennsylvania R. R. As will be seen by the engraving at the left in Fig. 93, the main rail is unbroken and continuous, but the turnout rail is in two parts, and is connected to, and operated by, the switch stand, so that when the switch is set for a siding movement the two parts of the frog are brought up against the main-line rail and locked in that position, as shown by the engraving at the right. The construction of the frog is such that it forms, in effect, a continuous rail for the passage of the wheels, and at the same time raises them up high enough to permit the flanges to pass over the top of the main-line rail. For siding movements the device fits over the main-line rail in a manner similar to the closing of the movable wing against the point rail in spring-rail frogs. It will be noticed that the frog has "safety wings" or inclined planes which fit over the main-line rail for some distance. This arrangement serves a double purpose: by thus lengthening out the movable wing on the turnout side the frog is given a desirable degree of stability, and there is secured a provision for the safety of a train on main-track which might find the switch wrong and the frog resting upon the main rail, in which event it would pass over the safety wings in the same manner that it would pass through an ordinary spring rail frog, and that without injury to either train or frog. There is also provided a means to prevent the frog being thrown prematurely, for switchmen would be liable to set the switch for the main line, after the last pair of wheels had cleared the switch, when entering the siding, thus removing the frog from the main line and causing a derailment. A device for overcoming this difficulty is a spring guard rail mounted to form an inside "protector bar" or spring rail, which normally fits up against the gage side of the lead rail, between the switch and ordinary guard rail, as is shown in the figure. The flanges of the wheels of a train in passing into the siding crowd back this bar and cause a hooked lug which is connected to it to engage with a notch or lug on the operating rod and thus prevent its movement until all of the wheels have passed safely beyond the frog.

The MacPherson Frog, designed by Mr. Duncan MacPherson, division engineer with the Canadian Pacific Ry., is one of the standard devices of that road, and is in service on quite a large number of other roads. Figure 94 shows the frog in both the open and closed positions. It consists of two parts, which are well clear of the main track rails when the switch is not set for the turnout, thus avoiding wear. One piece of the frog consists of a point rail, which is thrown up to the main rail at the proper angle for the frog, and the other piece consists of a rail curved or flared at the end to make a proper junction with the point rail, across the top of the main rail. These parts are high enough to overlap the main rail and carry the wheel flanges well clear of that rail. The frog is connected with the switch by pipe line and bell crank, both frog and switch being interlocked and thrown by the same movement of the switch stand, so that the frog is always set right for the position of the switch. A wrong setting of the frog cannot endanger trains on main line. Should a train on main line trail the frog when it is set for the turnout, the

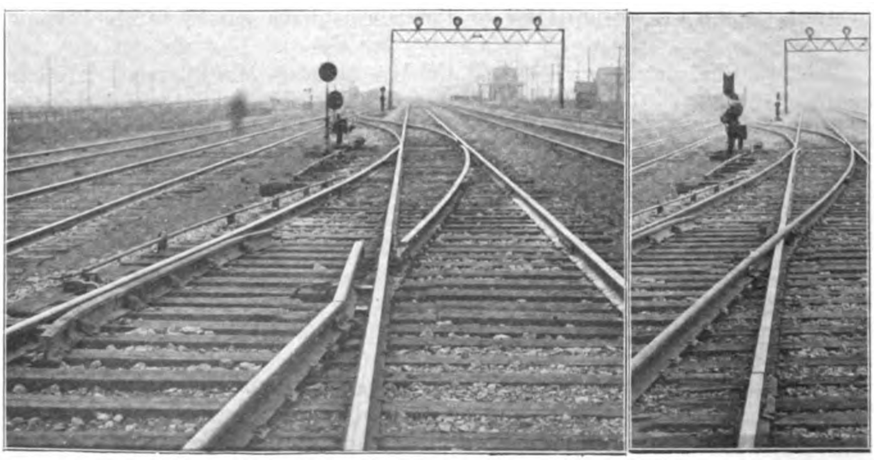


Set for Main Line. Set for Siding.

Fig. 94.—MacPherson Frog, Canadian Pacific Ry.

wheel flange would catch the flaring end of the frog rail and force it aside, while the outer portion of the wheel tread would force aside the point piece on the opposite side of the main rail. This frog may be used with any type of switch, either split or stub, by interlocking the movements of the two. On the roads where it is in service it is in some cases used with the ordinary split switch, and in other cases with the Mac Pherson switch, which is constructed on the Wharton principle and is described further along.

The Coughlin "swing-rail" frog, in use on the Western Maryland, Lehigh Valley and other roads, consists essentially of a piece of rail about 6 ft. long, which, when set for the siding, is swung diagonally across the main rail, in line with the fixed leads of the turnout. It is pivoted at one end and, when thrown for the siding, the other end rests in a seat at the fixed end of the turnout lead rail, with which it makes a miter joint. The hinge of the swing rail and the seat referred to are supported by a base plate, which extends under and supports also the main-track rail, but is not rigidly attached thereto. The swing rail is made from a piece of 100-lb. rail, with the base and web cut away from that portion which



Set for Main Line. Set for Siding.

Fig. 95.—Coughlin Swing-Rail Frog.

passes over the main line rail. The fixed ends of the turnout lead rails are elevated to conform to the swing rail, which carries the wheels 1¾ ins. above main rail, and is guided to the proper hight to slide across the main rail, by raising plates. Frog and switch are connected by a pipe line through a bell-crank, and both are moved by the same stand, which may be placed either at the switch or opposite the frog. In the operation of a specially designed switch stand of the cam class, intended for use in connection with these frogs, the first half throw of the lever sets the switch and the second half or completion of the throw operates the frog and locks the switch. In throwing the stand back to its position for main line, the reverse movement takes place, the frog being operated at the first half of the return stroke, and then the switch. When thrown to the siding the swing rail is locked in position against side or vertical movement by wheels on the turnout, but a tripping bar is provided which permits the swing rail to be pushed aside should a train on main track trail the frog while it is set for the siding. When set for the main track the swing rail is moved to a position parallel with the main-line rail, clearing by an ample flangeway, so that no guard rail is needed. It would seem proper, however, to use a guard rail in the turnout, opposite the frog. To prevent the frog from being thrown while a car is between

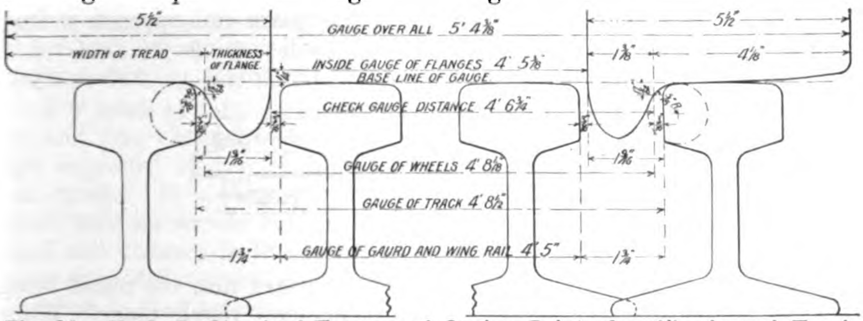


Fig. 96.—M. C. B. Standard Terms and Gaging Points for Wheels and Track.

it and the switch a detector bar is used. This device and its operation are described under § 82 of this chapter, on the "Machine Operation of Switches." See § 221 for the Coughlin-Sanford switch point lock.

Both the MacPherson and Coughlin frogs may be and are used without guard rails in the main track, and in connection with a Wharton switch they thus preserve the continuity of the rails and an unobstructed track throughout the length of the turnout—apparently a very safe arrangement for high-speed trains. They are not intended for use in yards or at turnouts where a great deal of switching is done. The prevailing disposition toward these devices seems to be to first try them at outlying turnouts in main line, that are used only occasionally, but where the speed on main line is rapid.

59. Guard Rails.—The purpose of the ordinary guard rail in turnouts is to so constrain the wheel flange that the flange of the wheel on the other end of the axle is kept clear of the point of frog. In order that this condition may obtain, the frog should be laid to exact gage and the wheels should be set according to measurements which conform to standard track gage. Unless both of these conditions be fulfilled wheels will not pass smoothly by the frog. Figure 96 shows a pair of wheels of standard shape, gaged according to the Master Car Builders' standard (4 ft. 8½ ins.), on track of standard gage. The gaging point of the wheels is on the flange fillet (the curve by which the flange meets the tread) $^{17}/_{64}$ in. out from the tread. This point on the fillet is the supposed normal limiting point of contact between the wheel and the rail. It will be seen that the width of flangeway, or space between guard rail and running rail, is $1\frac{3}{4}$ ins. This width of flangeway allows a play of $^3/_{16}$ in. between the back of wheel flange and guard rail, and the same amount of play between the back of flange and frog wing. When this play between back of flange and guard rail is taken up by the motion of a wheel the flange fillet of the mating wheel may then just reach the frog tongue, but the flange is held away, so that it cannot impinge upon the point when it comes facing; that is, when it approaches the frog from the direction of the switch. For wheels trailing a frog no guard rail is needed.

If the flangeway of the guard rail on track of standard gage be made wider than $1\frac{3}{4}$ ins. the wheel flanges will impinge on the point of tongue. If the gage at the frog be wider than 4 ft. $8\frac{1}{2}$ ins., as on a curve, the flangeway should be increased by just the amount the gage is widened, or the flanges will strike a heavy blow on the wing of the frog. In other words, the service side of the guard rail head, opposite the frog tongue, should be 4 ft. $6\frac{3}{4}$ ins. (4 ft. $8\frac{1}{2}$ ins.—$1\frac{3}{4}$ ins.) from the gage line of the frog, regardless of the gage of the track. As a rule which applies in all cases, then, the guard rail should be spaced not from the rail adjacent but from the gage line of the frog or the rail on the opposite side of the track. This rule is often overlooked when laying the guard rail opposite a frog, in the turnout. From the fear that flanges will impinge on the end of the tongue many trackmen make the gage at the frog $\frac{1}{4}$ in. wide without

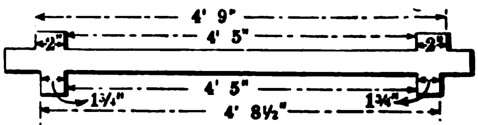


Fig. 97.—Guard Rail Gages.

making due allowance in the flangeway of the guard rail, the result being that the turnout wing of the frog must undergo rough usage. While there is no necessity for increasing the gage of the turnout at the frog, and while so doing makes an unsightly jog in the rail, still, whatever be the gage of the track, the guard rail should always be spaced the same distance from the gage side of the frog, as above stated. This distance, 4 ft. $6\frac{3}{4}$ ins., might properly be called the *guard rail distance.*

Wheels are supposed to be gaged according to the M. C. B. standard, or 4 ft. $6\frac{3}{4}$ ins. from the back of flange on one wheel to the gage line of the flange on the other. This measurement, called the *check gage distance,* is the same as the guard rail distance, and when such is observed, both guard and wing rail blows and point impingements are avoided. The standard distance between wheels is 4 ft. $5\frac{3}{8}$ ins., back to back of flanges, and to provide for variation in thickness of flanges a deviation is allowed between the limits of 4 ft. $5\frac{1}{4}$ ins. and 4 ft. $5\frac{1}{2}$ ins., which permits a maximum flange thickness of $1^7/_{16}$ ins., and a minimum thickness of $1^5/_{16}$ ins. (for new wheels). A standard distance back to back of flanges, is not, however, a consistent gage for mounting wheels in all cases, because if the flanges are not of standard thickness such a gage permits a comparatively wide range of measurements between gage lines of the flanges; that is, in the *gage of wheels.* For wheel flanges not of standard thickness there is only one logical basis of measurement, and this is from the back of one flange to the gage line on the flange fillet of the other. This measurement and the guard rail distance must be the same; otherwise the proper relationship of the wheels to the track at switches cannot be maintained.

Although the thickness of flange does affect the back-to-back measurement of wheels set to proper gage no harm results so long as this distance is not less than 4 ft. 5 ins.

Some complication appears to arise over the proper gaging of wheels with worn flanges; for although the ideal condition obtains with new wheels gaged in the manner just pointed out, both guard and wing rail blows follow upon appreciable flange wear, since the check gage distance then becomes less than the guard rail distance and the wheels have more lateral motion or play across the track. This trouble can be remedied by pressing the wheels farther apart an amount equal to the wear of one flange. This change restores the wheels to the standard check gage distance, and as long as this gage is not exceeded there can be no impingement on the point of tongue. It should be stated that the desired results from this treatment of worn wheels cannot be had unless the flanges be of equal thickness; but two wheels differing in thickness of flange to any appreciable extent should not be used on the same axle, since with such the check gage distance cannot be made to measure the same both ways over the pair. The M. C. B. rules permit a variation in thickness not to exceed $^1/_{16}$ in. With this precaution it must be plainly evident that a rigid adherence to the 4 ft. 6$\frac{3}{4}$-in. measurement between back and gage lines of flanges is the solution of the worn or irregular wheel flange difficulty. The M. C. B. rules require that wheels with flanges worn to a thickness of $1^1/_{16}$ ins. or less shall not be remounted.

For track of 4 ft. 9 ins. gage the standard width of guard rail flangeway and frog channel is 2 ins. Figure 97 shows the standard guard rail gage suggested by the M. C. B. Assn. for both standard-gage and 4 ft. 9-in. tracks. It is seen that the same distance of 4 ft. 5 ins. is maintained between service sides of guard and wing rails in either case. The guard rail distance in this case is 4 ft. 7 ins., thus exceeding the standard check gage distance by $\frac{1}{4}$ in. and permitting minimum guard and wing rail blows to that extent, from wheels of standard gage; if a frog of standard channel width (1$\frac{3}{4}$ ins.) be used the wing rail blow is increased to $\frac{1}{2}$ in. It is thus seen that on 4 ft. 9-in. track with 2-in flangeways ideal conditions for wheels set to standard gage are impossible.

It may be well enough to here call attention to the fact that the gaging point of wheels, although officially defined, has no fixed position, so far as may be determined from conditions of contact with the rail. The point or line on the wheel to which the gage is referred is that which is supposed to coincide with a plane which stands perpendicular to the track on the gage line of the rail, when the flange is crowding the rail to the limit of lateral movement. On a new wheel this point is supposed to be on the flange fillet, and it may or may not come in contact with the rail, even when the flange is crowding the rail to the limit. This supposed gaging point is not easily identified, even on new wheels, and on worn wheels it cannot be distinctly located. The limit of the lateral motion of a wheel relatively to the rail depends upon the shape of the top corner of the rail head and the condition of the wheel flange fillet respecting wear. The line of contact between flange and rail is not precisely determinable even with new wheels and rails, and it may change with wear of either wheel or rail. By means of models or observations of experiments with actual wheels and rails the gaging point can be located approximately for any assumed contour of wheel and rail. For the M. C. B. standards it was located for new wheels and a rail with a top corner radius of $\frac{1}{4}$ in. For the above reasons the technical thickness of wheel flange cannot be exactly determined. The only fixed point on the wheel from which definite gage measurements can be taken is the back of the flange, and no comparison of the wheel gage with that of guard rails, frog points and frog wing rails is reliable unless the back of the wheel flange is made the basis of measurement.

So far as danger of impinging on the frog tongue is concerned, there is no necessity for maintaining the guard rail distance except at the point directly opposite the point of tongue. In fact such an arrangement is in practice on some roads, including the Great Northern Ry. The guard rail is bent sharply at the middle with a jim-crow and the bend is placed opposite the point of tongue at the proper guard rail distance. For several reasons, however, it is considered better practice to lay the guard rail parallel with the gage line of the frog for some little distance, at least 3 or 4 ft. In the first place, the wear on the straight piece of guard rail is not so rapid as it is on the small amount of restraining surface presented by a sharp bend. There is an element of safety in maintaining the guard rail at the proper guarding distance (4 ft. 6¾ ins.) for some distance in rear of the point directly opposite to the point of tongue. Sometimes a loose or widely-gaged wheel or a wheel on a bent axle will ride the point, and if there is a foot or two of straight guard rail at the proper gage distance the wheel is likely to be brought back again. With spring frogs the length of guard rail set to proper guard rail distance should at least cover the movable wing in advance of the point. This arrangement relieves the spring rail from side pressure, particularly if the frog is on the outside of a curve (where a spring-rail frog ought not to be), and it reduces the risk of derailment in case the spring rail should break or some other accident happen to the frog.

The flare at the ends of guard rails is usually 4 to 6 ins. from the running rail, and it should be made gradually, say in a distance of 4 to 6 ft., so as to draw the wheels to the guard point without jar or shock. The easier or more gradual the flare the better is the guard rail able to withstand the side blows from badly gaged wheels or wheels with badly worn flanges which have not been regaged. If the rail is of proper length it can be sprung to make the flare without curving, but if it is short it should be curved. The practice of heating the rail and bending or curving the ends within the short distance of a foot or two is a bad one and produces a poor guard rail, which is the cause of unpleasant riding. There can be no doubt but that car axles are often severely strained, if not broken, by the sudden jogging of the wheels against short guard rails, or against those which are curved or bent at the ends too suddenly. In order to strengthen the guard rail against overturning it is quite extensively the practice to flare the ends 8 to 12 ins.; in which case tilting or overturning cannot take place except by a square lift at the center of the rail. For the same purpose it has been the practice with a few roads to turn the ends of the guard rail at right angles, toward the center of the track, for a length of 18 ins. or so. In the instance of one road whereon this principle has been adopted the head and web are cut from the squarely bent ends and three holes are punched through the base which remains, for spiking these ends to the ties. No spikes are then driven in the flangeway to hold down the straight portion of the guard rail, which is 7 ft. in length, the total length of the guard rail before bending being 12 ft. On the Michigan Central R. R. the flare of each end of the guard rail is made in two distinct bends, one 2½ ft. from center to give the flangeway a gradual taper and the other 5½ ft. from center and 2 ft. from the end of the rail, to bend in a short portion to a clearance of 8 ins. from the running rail, for stability against "rolling" or tilting.

Guard rails should be at least 18 ft. long and are all the better if longer. A guard rail as short as 8 or 10 ft. in length, without reinforcing devices, is easily torn out by derailed wheels, if it does not get loose from ordinary service. A long guard rail can be firmly held in place by the spikes alone, and it affords plenty of rail to make a gradual flare. Guard rails placed on the inside of curves should be a full rail's length. They can be flared for a gradual approach to the necessary guarding point, and if the portion parallel to the running rail be restricted to a short length at the middle the unusual length will not increase the liability of the wheel flanges to bind in the flangeway. Where a turnout is laid only temporarily, and there happen to be no pieces of rail of convenient length for guard rails, it is well to use a whole rail in preference to cutting it. The guard rail should be placed centrally opposite the frog point or nearly so (as the ties at the ends of the guard rail will determine), not only for sake of appearance but because the wheel should be guarded as gradually while trailing the frog as when moving facing to it; for while there is no need of guarding a wheel trailing a frog, still the guard is there and the wheel flanges must meet it just the same as when they come facing. It is quite commonly the practice to lay the guard rail with its center in advance of the frog point. The standard practice of the Philadelphia & Reading Ry. is to lay guard rails opposite frogs to bring the middle point 2 ft. 8 ins. in advance of the frog point.

The top of the guard rail should not stand higher than that of the running rail, as if it does it comes in the way of, and is liable to receive heavy side blows from, the inside false flange of blind drivers, the tires of which are wider than those of the flanged drivers and are usually placed closer back to back. Neither should the top of the guard rail be much lower than that of the running rail, as if it is some of the effectiveness of the rail as a guard is lost. On a certain road where it was attempted to use 75-lb. guard rails with 100-lb. running rails, without raising the former off the ties, it frequently happened that the wheel flanges would climb the flared ends of the guard rail and cause derailment. On the Burlington & Missouri River R. R. the guard rail is set to bring its top $\frac{1}{8}$ in. lower than that of the running rail, in order to escape interference with worn blind drivers, as just explained.

Old flange-worn rails from the outer side of curves make good guard rails, as they are already curved and serve the purpose just as well as a new rail. Old iron rails have been much used for guard rails but are now becoming scarce and are of too small section to match with the new rails laid in these days unless chairs or raising blocks are used to bring the top of the guard rail to proper hight. Figure 99 shows the form of cast chair and brace in service on the Southern Pacific road, designed to allow the use of a 50-lb. guard rail with a 75-lb. or 76-lb. running rail. The casting is ribbed, as indicated by the broken line, and is set upon a special Servis tie plate 12 ins. long and 5 ins. wide, with two spike holes punched to come at the edge of the chair. Three of these chairs are used on the standard guard rail (10 ft. long), one being placed at the middle and one near each end, where the bend is made for the flare, the length of the straight portion of the guard rail being 7 ft. 4 ins. By means of a bolt and a pipe filler or spacing sleeve the two rails are securely braced together.

The ends of a guard rail cut off squarely, as they usually are, form ugly obstructions to snow plows and flangers and to parts of brake rigging which may be hanging loose or dragging, and oftentimes such parts are torn loose at guard rails and cause derailment. Moreover, trainmen are occasionally injured by stubbing against them and falling, even though the ends of the guard rail are blocked; for foot guards usually pass under the head of the rail. It is therefore a good plan to have the ends of guard rails sloped down to the rail base, something like the end of the piece shown in Fig. 98. By heating the end and cutting out a triangular portion of the web the head is bent to slope down to the base and a hole is punched through the end for a spike. Guard rails made in this way will not catch and hold anything which may be dragged against them, and they are therefore not so liable to be torn out. Pieces of rail of lengths suitable for guard rails may be sent to the shops to be so shaped and then stored until needed. Short pieces of rail 2 or 3 ft. long which cannot be utilized in making frogs, and which usually go to the scrap pile, may be utilized in this way by splicing on to the ends of guard rails already laid, using old fish plates for splices. On some roads the ends of

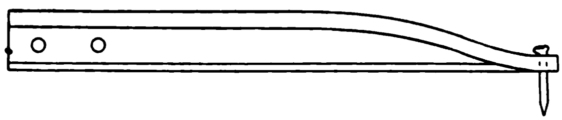


Fig. 98.—Sloped End Piece for Guard Rail.

the guard rails are sawed off to a slope. This is a much better arrangement than the squarely cut ends, but the sharp under corners at the end of rail head still have some tendency to catch things dragged against it.

Before laying a guard rail which rests upon the ties metal must be taken from the edge of the flange which comes next the running rail or notches must be cut out of the same, to afford spiking space in the flangeway. Unless the flanges of the two rails interfere with bringing the heads to a proper flangeway it is better to notch out for the spikes than to plane or chip off the edge of the flange along the whole length of the straight portion. The best way to take off a strip of the flange or to cut out places for the spikes is to turn the guard rail on its head, notch out with the track chisel, in outline, on the base, the strip or portions to be cut away and then break them out with the hammer, slanting the stroke inward toward the rail web. Some go to needless pains in work of this kind, by laying a piece of rail for an anvil and cutting full depth to remove the necessary metal. As either steel or iron rails will break to a notching it saves much time and effort to merely notch the metal and break it off. In fact the metal is sometimes broken off without notching with a chisel, but the work is irregular and no time is gained.

The way to lay a guard rail is to place it in position and spike the portion opposite the frog point first. A sharp pick is an excellent tool to use in case the rail must be sprung to place while spiking it. After the middle portion is secure for the whole distance over which it is to be laid parallel to the running rail, spring out the ends, if they are not already curved, and secure them in the proper position, after which spike down the remaining portion of the rail, both sides, throughout, double-spiking the ends and the middle portion, if the rail is to be held by spikes

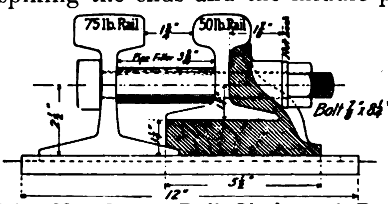


Fig. 99.—Guard Rail Chair and Brace. S. P. Co.

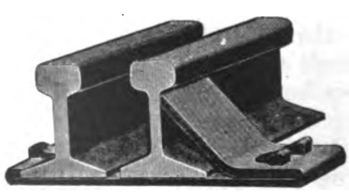


Fig. 100.—Edwards Guard Rail Brace.

Fig. 100 A.—Graham Guard Rail Brace, Southern Ry.

only. In some cases guard rails are secured by spikes alone; and if the rail is of good length it may remain quite firmly in place while the ties are new; but there is considerable leverage tending to overturn it inward to the track, and it is now extensively the practice to fortify guard rails with some form of brace.

Guard Rail Braces and Clamps.—There are many ways of bracing or giving additional security to guard rails. A common practice has been to tightly fit one or more pieces of 3-in hardwood plank endwise between the webs of the guard rail and frog wing, spiking the plank to the top of a tie. This method, however, is open to the objection that the planking is in danger of being torn out at any time by dragging brake rigging. The Graham guard rail brace is a metallic device applied in the same way. It consists of a pressed steel strut of inverted U-section, flanged for spiking to the ties, and reaching from guard rail to frog wing (Fig. 100A). The ends conform to the shape of the side of the rail web and head, like a rail brace. It is used on the Southern Ry. and other roads.

Ordinary rail braces are commonly used for the purpose, spaced symmetrically each side the middle of the rail. Four braces—one at each end of the straight portion and one at each end of the rail—answer very well. A very secure way is to drill holes through the webs of the guard and running rails and through these to bolt the guard rail fast to the running rail, using 1-in. bolts. Spools or spacing blocks should be used with the bolts, so as to permit the nuts to be turned on tightly without tilting the guard rail or narrowing the flangeway. Heavy washers for the outside, made by cutting up old fish plates, are sometimes used. A heavy clamp, similar in design to a frog clamp, placed opposite the frog point, and sometimes at the ends of the straight part of the guard rail, is used to

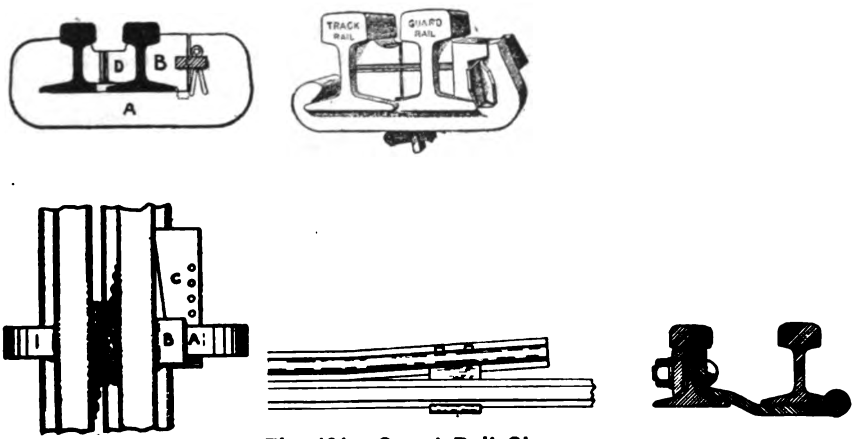


Fig. 101.—Guard Rail Clamps.

some extent. At the left in Fig. 101 there is shown the Wharton adjustable guard rail clamp. It consists of a heavy forging A, a cast filler D, a cast wedge block B and a steel wedge C, with cotter pin. The cast filler D is composed of two similar triangular-shaped pieces with rounded saw-tooth projections, which, as they are moved by each other, give variations in the opening of the flangeway to suit any desired adjustment. The device shown in the upper right side of the figure is the Pennsylvania Standard guard rail clamp made of iron 4 ins. wide and 1¼ to 1½ ins. thick, according to the size of the rail. The metal spacing blocks are secured by a vertical flat key bolt and split key driven under the clamp, and the clamp is tightened and secured by driving the horizontal soft steel wedge and spreading open the split end. The device shown in the lower right side of the figure is in use on the Chicago & Western Indiana, the Chicago, Rock Island & Pacific and other roads. It is a steel plate clamp 10 ins. wide and ½ in. thick, bent up at the inner end to bolt to the web of the guard rail and formed into a clasp at the outer end, which

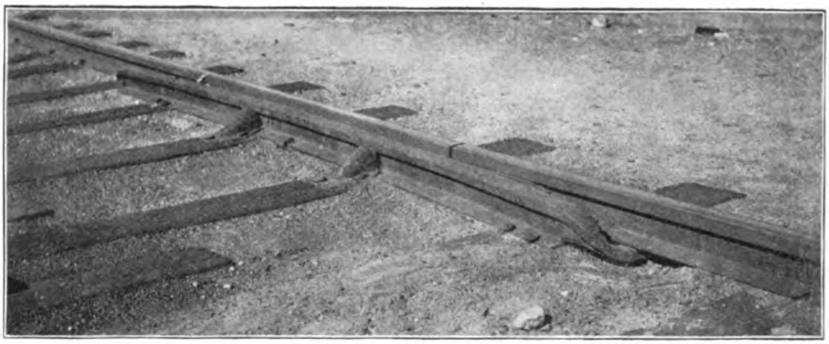


Fig. 102.—Standard Guard Rail, Maine Central R. R.

is passed under the running rail and hooked over the edge of the flange. It is applied to the flared end of the guard rail, as shown in the plan view, and the adjustment is by means of a series of holes in the end of the guard rail, the clamp being moved to bolt on nearer to or farther from the end as a narrower or wider flangeway is desired. The Edwards guard rail brace (Fig. 100) is made all in one piece, to fit under the head of the guard rail on the off side and to hook around the outside edge of the flange of the running rail.

The standard guard rail of the Maine Central R. R. has ends bent to form clamps, as shown in Fig. 102. The guard rail is 10 ft. long, bent at the middle and flared to a clearance of 4 ins. at the ends. At each end of the rail the base and web are cut out to leave a projecting piece of the head 12 or 15 ins. long, and this head is turned down like a ram's horn, passed underneath the running rail and clinched over the base on the other side. In some cases, however, the head and web are cut away and the flange (instead of the head) of the guard rail is bent under and around to embrace the outer flange of the running rail. The arrangement holds the guard rail securely against canting or being torn out by derailed wheels or dragging parts.

The method of securing the guard rail to the running rail, in any manner, is opposed by some trackmen on the ground that the position of the guard rail is thus dependent upon the stability of the rail to which it is attached, whereas it should be maintained in position with reference to the frog regardless of the position of the rail opposite. If the guard rail is laid at the proper distance from the frog, however, the objection is not serious, because the running rail, by itself alone, is ordinarily secure enough for a guard rail, and if the guard rail is well spiked (as it should be) there is but small probability that the two will be moved out of gage. Of course the true principle would be to unite guard rail and frog instead of guard rail and running rail, and those inclined to the position stated claim that if anything in the nature of a guard rail clamp is worth having at all it should be such as will secure the guard rail to the frog; in other words preserve the proper gage of guard and wing rails. As a suggestion on this idea I am indebted to Mr. D. M. Taylor for the sketch of a proposed device shown as Fig. 103. It consists of a round bar threaded into a steel casting bolted to the guard rail, at one end, and flattened at the other end or so shaped as to be most conveniently fastened to the frog. The steel casting (*A*) might be similar, in shape and method of attachment, to some switch lugs now in use, but quite heavy. If the gage bar

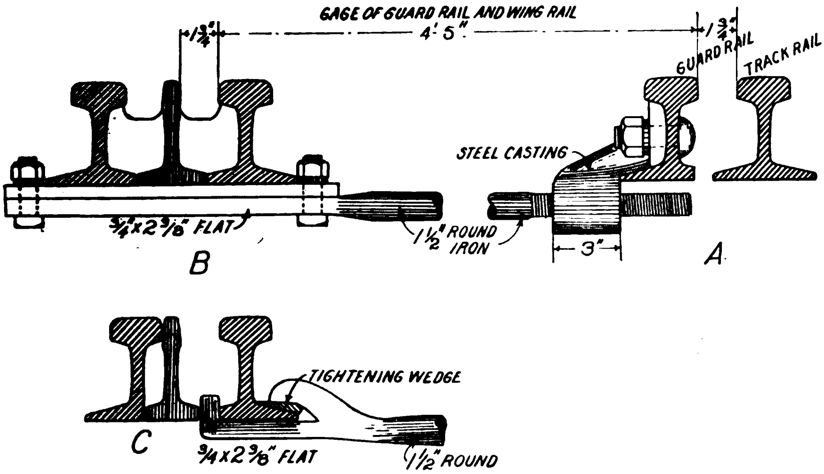


Fig. 103.—Proposed Device for Holding Guard Rail to Gage.

was to be attached to a plate frog the simplest method would perhaps be to use bolts as shown at *B*, and as the service stress on the bar would be that of compression, there might be a shoulder on the bar to abut against the frog plate. If it is to be attached to a spring frog without plate the end of the bar might be forged into some such shape as is shown at *C*, admitting of easy removal by simply knocking out the tightening wedge which holds the bar to its place in a manner similar to that sometimes used with clamped frogs. The device would certainly be practicable, and would not probably cost any more than some of the guard rail clamps now in use. Further on the matter of guard rail clamps, it may be stated that one objection to the use of a non-adjustable filling block between main and guard rail, bolted through and through, is that it does not permit the guard rail to be reset and moved in to a proper flangeway when the service side becomes unduly worn.

An interesting departure in guard rail design has been in satisfactory service for several years on the Duluth & Iron Range R. R., in the shape of an angle bar guard. This device was first designed for use with 100-lb. rails and spring-rail frogs, but has since been adopted for use with spring-rail frogs in 80-lb. track. The design shown in Fig. 104 is for 100-lb. track, the rail being 5¾ ins. high, 5¾ ins. wide on base, with a head 2¾ ins. wide. The guard rail is 20 ft. long and made of a 6x6x ¾-in. steel angle fitted in the factory and shipped with the frog. All the details and measurements are given on the engraving. It will be noticed that there are seven cast spacing blocks, in three sets, with bolts for securing the guard angle firmly to the running rail. The guard

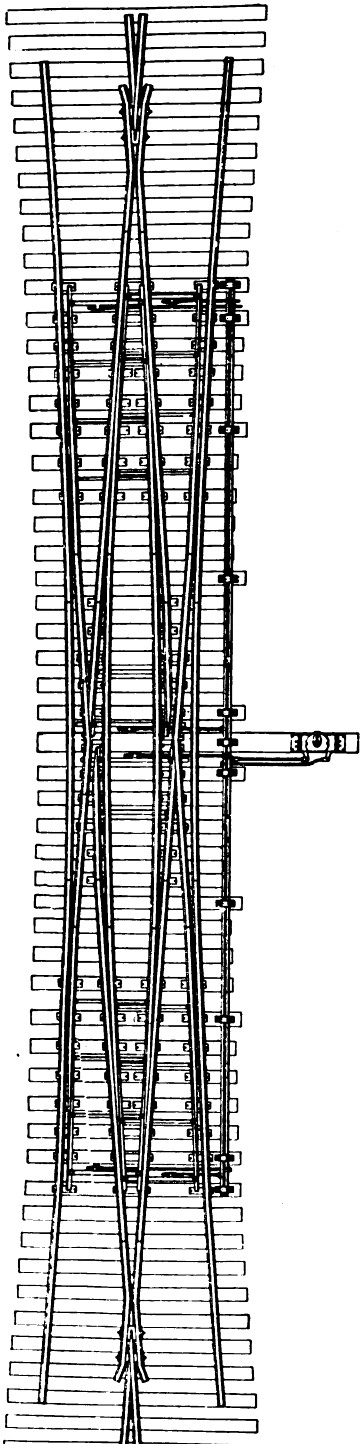
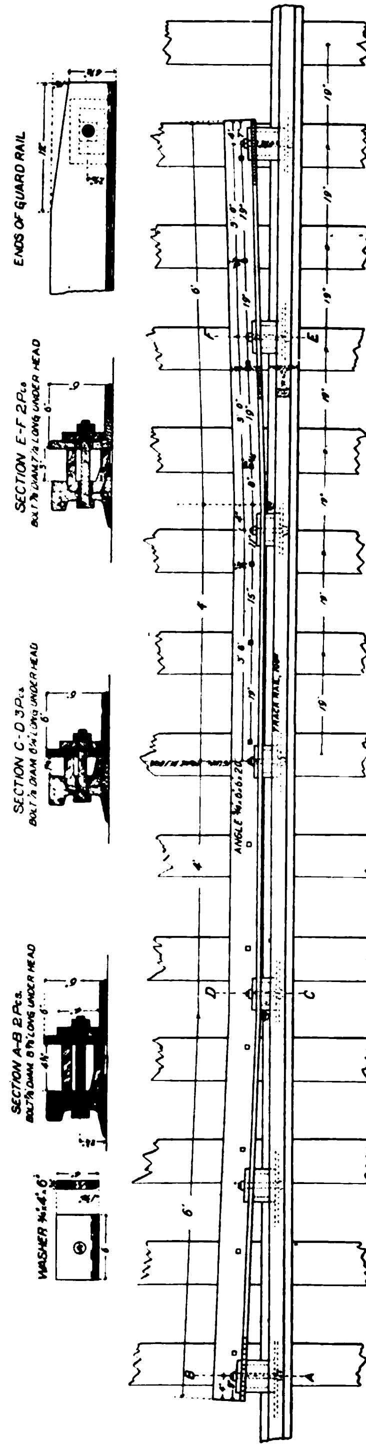


Fig. 104 A.—Elliot Rocker-Shaft Connection for Operating Movable-Point Frog and Slip Switch.



104.—Angle-Bar Guard Rail, Duluth & Iron Range R. R.

angle is further secured by spiking it to the ties through punched holes, spaced to correspond to the standard tie spacing. The ends of the guard angle are sloped down 1½ ins., in 12 ins., as shown, to make it less obstructive to loose parts of rolling stock. The angle bar in place weighs about the same as a 100-lb. T-rail of corresponding length used for the same purpose. A commendable feature of the design is the length of the guard rail, and another is the large portion of the length which is given to make the flare—six feet on each end, leaving 8 ft. of the guard rail straight or set to a 1¾-in. flangeway. On some of the railways of Germany guard rails of similar design are in service, the difference being that a bulb angle is used instead of a plain angle bar. This bulb angle is a specially rolled shape, the bulb projecting from the outside of the vertical leg of the angle instead of from the inside, as in the regular commercial shape; that is, the bulb is on the service side of the guard angle.

For various causes guard rails sometimes need to be taken up and reset. Among these causes are the spreading, canting or rolling of the guard rail, from wheel pressure; wearing away of the service side of the head; the wearing down of the running rail or the cutting of the ties under this rail, which leaves the guard rail too high for the worn tires of blind drivers. Deeply guttered blind tires are severe on guard rails and frog wings in any case, because they are usually 1 to 1½ ins. wider than the flanged tires and set in closer back to back, so that the inner false flange which runs into the flangeway of the guard rail must either climb out again when it meets the flared end or crowd against the guard rail with tremendous force. The coning of blind tires on the inside and outside of the tread helps matters for guard rails and frog wings when the tires become worn.

Another cause of the loosening or the spreading of guard rails arises in winter, when the flangeway gets closely packed with snow. It will thaw and then freeze and expand, but owing to the shape of the cavity the expanding material cannot easily force itself out, and consequently there is exerted a powerful force tending to spread the two rails apart. This trouble may be avoided by blocking the guard rail its whole length. For blocking the flangeway along the straight portion of a guard rail the channel filling of worn-out frogs comes handy, and is sometimes used. Being of the proper width and shape all that is necessary is to drill holes in the guard and main rails corresponding to some of those in the filling blocks, and then bolt the guard and main rails together like the wing rail and point pieces of a frog.

60. Switch Rods.—A switch rod, sometimes called a "bridle rod" or "tie bar," is an iron bar having slots or connections near or at its ends to fit the flanges or webs of the two switch rails, to hold them to gage. A stub switch rod is usually made from 1⅝-in. or 1½-in. round iron. If it is designed to gripe the rail flange it should be a forging rather than a rod with cleat attachments for this purpose. It ought to fit snugly the two rails at exactly standard gage distance apart. The rod placed next the headblock is usually extended a few inches beyond the slot on one end and flattened and drilled, to join with a connecting rod to the switch stand; it is sometimes called the "eye bar," "neck rod," or "head rod." This rod should fit the rail flange so closely that it must be driven on in order to get it to place. The bolt joining it to the connecting rod should fit both it and the connecting rod snugly. This rod should be placed as near the headshoe as it can be worked, so as to make the throw of the ends of the moving rails correspond as nearly as possible to the throw of the connecting rod or the switch stand. It should also be placed squarely with the two rails; that is, perpendicular to each switch rail when set for the main track. It can be kept from slewing around by a guard attached to the headblock, or by driving two stakes beside it into the ballast. With the stub switches of the Grand Trunk Ry. the head rod is a flat bar about 4 ins. wide and 1 in. thick, supporting the moving rails and sliding on a flat headshoe to which the stub ends of the lead rails are secured by riveted lugs.

A loose rod may be made to fit snugly by driving a key between the edge of the rail flange and the end of the slot, and then clinching the key. If the rails do not then come to gage and there is not room in the slots to permit them to be adjusted the necessary amount, the adjustment can be facilitated by trimming from the edge of the rail flange and keying it over that much. For this purpose switch rods should be so slotted that the part of the slot for the rail web is wider than the thickness of the

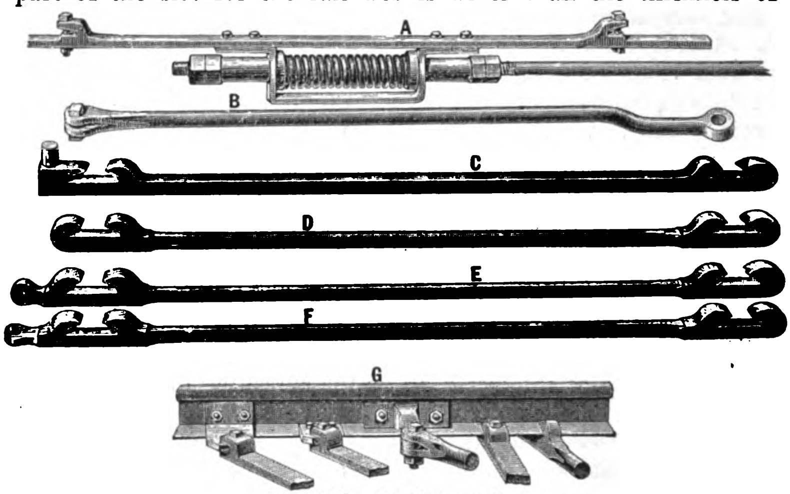


Fig. 105.—Switch Rods.

web by at least ½ in., thus making it possible to key and adjust the rail flange. If the rods are not all pretty nearly of the same gage this adjustment should always be made, so as to put the two rails to the same gage throughout. Different sizes of wire nails and telegraph wire make excellent keys for this purpose.

In order to protect the rods from getting bent in derailments, which will occur more or less in switching at stub switches, a sawed tie should be placed each side of each rod, leaving a space of about 2½ ins. between the ties for the rod; but unusually wide spaces should not be left between the other ties with the idea that bunching two together in a place will make up for the unequal distribution. It is at all events a good plan to have ties closely spaced under moving rails, in order to hold up the wheels in case of derailment. Ties placed in this manner also keep the rods to place. In case rods become badly bent one should not attempt to straighten them cold; but build a fire and heat them, before straightening. Ballast should not be dressed between the ties to reach the rods, and before winter sets in particular attention should be given to the matter to see that the ballast is everywhere clear of the rods, and that little trenches are dug, if necessary, to drain the spaces about the rods. The necessity of such precaution is to prevent the rods from freezing fast.

Figure 105 shows an assortment of switch rods. The rod *D* is the ordinary stub switch rod or "back rod," and the right-hand connection on

G shows the way it gripes the rail flange. Rods *C, E,* and *F* are different forms of head rods, *E* being for use with a ground switch stand and *F* with a revolving switch stand. Rod *B* is a connecting rod made to join with the head rod *F*. The four connections shown to the left hand on *G* are some ways of attaching rods to point switch rails; other figures in this chapter show still other methods. The rod *A* has the well known Lorenz spring or safety connection for point switch rails, referred to further on.

61. Headshoes.—Headshoes or "headchairs" are made either of cast iron, wrought iron or steel plate. A cast shoe, if thick enough, will give good service. A wrought or steel plate shoe is made by riveting properly shaped lugs or stops to a heavy plate. They will not break in two, as cast shoes do sometimes when engines or cars get off the track, but when poorly made the parts get loose. A cast shoe should be at least $1\frac{1}{2}$ ins. thick underneath the rails, and for heavy traffic the thickness should be 2 ins. It should be cored to fit snugly the section of the rail used with it. The metal should, of course, be tough and of good quality. A large proportion of the headshoes in use are badly designed in one particular: there is at the

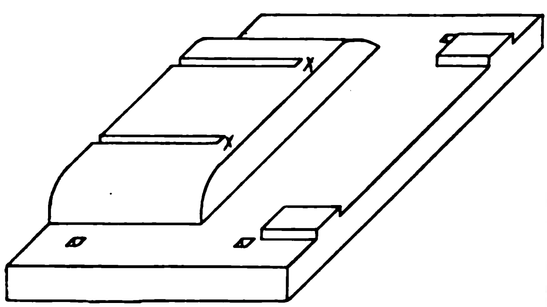


Fig. 106.—Cast Iron Headshoe.

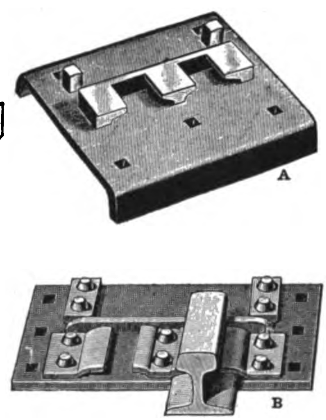


Fig. 107.—Steel Plate Headshoes.

back of seat of the stub or lead rail—that is, between the lead rail and the moving rail—a backing or ridge on the cross bar ("X," Fig. 106) $\frac{3}{4}$ to 1 in. thick, thus requiring the joint to be unnecessarily wide. There is no necessity for a thickness of metal at the back of seat of more than $\frac{1}{8}$ in. If it is not more than that the joint can be reduced to $\frac{3}{8}$ or $\frac{1}{4}$ in., and thus the heavy pounding due to a wide joint can be avoided. To prevent this thin wall of metal or backing from breaking out by the creeping of the rail, the corners of the slot for the rail flange should be cast solid, thus requiring the corners of the flange of the stub rail to be clipped off in order to fit the space. This arrangement provides plenty of metal as an abutment for the end of the rail. A headshoe with a thick wall back of the seat can be made to answer, however, by cutting out with a hack saw a piece from the flange and web at the end of the lead rail or moving rail, so as to allow the head of the rail to project over the backing or ridge, and in this way reduce the opening at the joint. The Ramapo headshoe (*B*, Fig. 120) is well designed in this respect.

In Fig. 107 are shown two forms of steel plate headshoe. The Buda rivetless headshoe *A* is the standard form on the Union Pacific road and *B* is the Elliot headshoe. The former is of $\frac{5}{8}$-in. rolled steel plate, with dependent flanges to fit over the sides of the headblock, to hold the headshoes square with the block. The lugs for holding the rails in their seats are held to the plate by bosses of rectangular section which extend through the plate and are countersunk on the under side thereof. There is a design of headshoe which relieves the connecting rod of the duty of holding the moving rails to position. For this purpose there is a rib or lug between the main and side-track positions on the seat for the ends of the moving rails, so that in either position of the switch the ends of the moving rails rest as it were in a rut. In order to throw the moving rails from one position to the other it is necessary to lift them out of these ruts or over the intervening lugs, and this is done by means of a foot lever which holds the rails above and clear of the lugs while they are being thrown. This device is in use on the Chicago & Western Indiana R. R.

The spike holes through a headshoe should be square and no larger than will nicely let a spike through. The headblock should be made smooth and even, where the shoe rests upon it. The two shoes should be cast from the same pattern and should be spiked to place at standard-gage distance apart respecting like points in each. The proper way to lay them, however, is to first fit them to the lead rails and then to spike them down with the gage resting upon the stub ends of the lead rails. Headshoes should be set squarely across the track; that is to say, squarely with the rails for main line. If a headshoe is set skewing it gives trouble when moving rails are expanded by heat and shoved tightly against the back of the sliding seat. Where the headshoe is set squarely with the rails for main line the switch may be thrown, even though the rails are shoved up tightly, by the assistance of a hammer or coal pick, with some oil. If the shoe is so skewed that there is less room for the moving rail when thrown for the turnout, the rail cannot be driven over; if, however, the shoe is skewed the other way, the switch rail, after being driven or thrown to the turnout, will expand so that it cannot be driven back to main line again.

62. Switch Stands.—An early form of switch stand, commonly known as the "harp" pattern, consisted of a straight lever held upright in a harp-shaped frame, carrying a target on its upper end, the connecting rod being attached to the lever either above or below the pivot point of the latter. This simple device furnished a cheap and reliable means for holding and throwing the switch rails and, during daytime, showed plainly enough the position of the switch, since, when set for the side-track, the lever had to be thrown out of its normally vertical position. It was not, however, adapted for a conveniently arranged switch light, for which reason it long ago went largely out of use on main line and other tracks where night indication of the position of the switch became important. Old stands of this pattern are now sometimes seen in yards, and in a few instances it has been fitted with an attachment for a switch lamp and is used on main line, such being the case on some parts of the Baltimore & Ohio and Baltimore & Ohio Southwestern roads. This attachment usually consists of an upright rod carrying the lamp, the rod being revolved by means of a crank in gear with the lever or with the main connecting rod.

The switch stand in general service for main track is the revolving stand, consisting principally of four parts—an upright frame, a shaft, a lever and a target. The shaft usually stands in a vertical position, the bottom end being turned up for a crank, to which is attached a rod connecting with the switch rails. The shaft is usually held in an "open" or "closed" cast iron frame secured to the headblock. The "closed" pattern frame is usually a cast iron shell or cylinder, and is sometimes called a "column stand." A lever, which can be thrown around horizontally, is attached to the shaft. The upper portion of the frame is usually flanged out to form a "table" or "top plate," the edge of which is notched to provide rests to hold the lever firmly in certain positions corresponding to the different positions of the switch, provision being also made to lock the lever fast in any of these positions. The lever is usually hinged to a collar which is keyed to the shaft, so that the outer portion of the lever can be turned down when being placed in the rest notch, thus leaving no parts projecting; this arrangement is commonly known as a "drop lever." As far as moving the switch is concerned these three parts—the frame, the shaft and the lever—are the important parts, and each should be composed of as few pieces as possible; multiplicity of parts gives rise to lost motion. The frame or stand proper should, if practicable, be in one solid casting, and the shaft and crank, one piece or forging; the lever, if hinged, must consist of two pieces, one of which is usually a collar projecting outward from the shaft, the outer end of the lever hanging vertically for the normal position. Near the upper end of the shaft, or on another shaft geared to it, is placed a banner or target to denote the position of the switch. The foregoing general description applies particularly to what is commonly known as a rigid stand.

General Principles of Design.—With any stand rigidly attached to the switch rails two things, among others, are required for satisfactory operation, namely an exact throw, corresponding to that of the switch, and, as far as possible, absence of lost motion. A poor stand used with a stub switch is a costly affair. The cost of derailments caused by lip, and the time spent driving keys, adjusting the position of stand, headshoes, etc., will soon amount to more than the difference in cost between a good and a poor stand. With point switches using a spring connection with the stand, thus affording a means of adjustment for taking up lost motion, the throw of the stand need not be so exact, and some stands might serve the purpose quite well which would not answer at all for rigid connections. Rigidly-connected switches whether point or stub, require closely-throwing stands, but good stands should be provided in all cases, because stands are sometimes changed about, especially in yards or in temporary construction. Besides being well designed, switch stands should be well and carefully made. A forged shaft connected to castings in the rough will soon wear and accumulate lost motion, no matter how close the fitting at first. The parts of the shaft which fit into the casting should be turned in a lathe, the bearings in the casting should be reamed, and all joints whatsoever should be made to fit closely and accurately. The crank pin should be turned and the eyes of the connecting and head rods should be reamed to fit the bolts closely. All joints where there is movement of parts should be either accessible or provided with oil holes, for switch stands, to work easily, should be kept oiled. A good stand cannot be made without considerable machine work.

An important point too often overlooked in the design of switch stands is in regard to the throw. A stand whose crank is the same length as the throw of the rails, and which is made to be revolved through 90 deg. from a position of the crank which is either perpendicular to or parallel to the switch rails, will really move the rails more than the desired throw, when the crank is turned out of a position perpendicular to the switch rails, *from* them; or out of a position parallel to the switch rails, *toward* them. When turned out of a position perpendicular to the switch rails, *toward* them; or out of a position parallel to the switch rails *from* them it will move the rails less than the desired throw. To make this matter clear we refer, in Fig. 108, to a concrete example. Let D E represent the near moving rail, C H the head rod, C B the connecting rod and A B the crank of the switch stand. Suppose $A\ B$ to be 5 ins. and $B\ C$, the connecting rod, 55 ins. in length; then the point C is distant from the fixed point A, $55+5=60$ ins. Now turn the crank around 90 deg., or from the position $A\ B$ to $A\ B'$. C will then move to position C' and the distance from A will be the square root of $(55^2-5^2)=54.77$ ins. The point C and the moving rails have then moved a distance$=60-54.77=5.23$ ins., or about $\frac{1}{4}$ in. farther than the intended throw—enough to give bad lip, unless there is lost motion in the stand or the turnout lead rail fits the headshoe loosely enough to be keyed over that much to meet it. The variation between the throw of the rails and the length of the crank is the same for the other ways spoken of and is determined in the same manner.

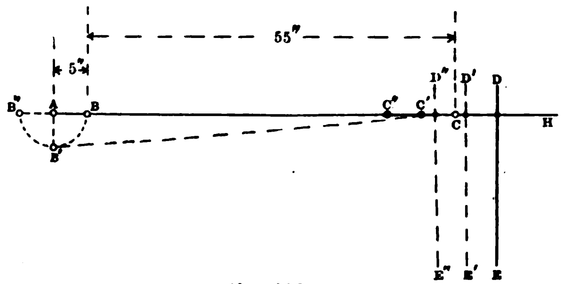


Fig. 108.

Manufacturers sometimes leave enough lost motion in the stand to make up for this variation, but it works in only two out of the four possible ways the stand may be used, as heretofore enumerated. In the other two ways, the real throw being less than the intended throw (equal to the length of the crank), the movement in the rails will fall short of the intended throw by the variation just calculated added to the lost motion, thus making matters all the worse. And so it is that trackmen in setting switch stands sometimes have difficulty in getting the stand to throw the rails without lip: they have struck one of the two ways in which the lost motion works in a manner contrary to that intended. Now, no crank of length other than the throw will answer for this stand, for while in the two cases of increased throw a shorter crank would do, in the other two cases of decreased throw a longer one would be needed, and obviously it could not be both for the same stand; and for convenience every stand of this kind should be so made that it can be set either to push or pull the moving rails when turned from a position in which the crank stands on the dead center or perpendicular to the moving rails when set for the main line. This is called setting the stand "the strong way for the main line," referred to again further on. As lost motion only makes the difficulty worse in two cases out of the four possible ways of using the stand, and is objectionable for other reasons, evidently this kind of stand cannot give entire satisfaction in two-throw stub switches as they are found.

These problems of adjustment can be overcome by setting the crank so that it turns through an angle of 90 deg., from a position in which it stands at an angle of 45 deg. to the direction of the moving rails before throwing. It will be seen, in Fig. 109, that if the connecting rod BC be perpendicular to the moving rail $D\ E$ before being thrown, it is practically perpendicular after being thrown, and $C\ C'$ is therefore practically equal to $B\ B'$. The triangle $B\ A\ B'$ being necessarily isosceles, and the angle $B\ A\ B'$, 90 deg., $B\ B'$ (the throw) being the hypotheneuse of an isosceles right triangle will be $\sqrt{2}$ or 1.41 times the length of crank, in every case. This manner of setting the crank is the better arrangement for a quarter-turn stand and hence the better one for two-throw switches in general, although it does not permit setting the crank on the dead center for any position of the switch.

Referring again to Fig. 108, let us consider a stand for use with a three-throw switch. It must be revolved through an angle of 180 deg. while passing over from its extreme position one way (AB) to the other extreme position (AB''); and as the connecting rod in both positions is perpendicular to the moving rail (practically so) the throw is right for these two positions. The position of the crank when properly set for the middle track, however, will not be midway between, or 90 deg. from, these two positions (if the throw from the middle track each way to the others be equal, as it always is) for the same reason which applied to the two-throw switch, heretofore explained. The position of the crank for the middle track will be a certain number of degrees measured around from B'', or B, accordingly as the stand is on the left or right hand as one stands at the headblock looking toward the frog, the exact number of degrees depending upon the length of the connecting rod BC. With the throw 5 ins. and the connecting rod 55 ins. long, the angle would be 87 deg. 24 min. For a three-throw switch, then, the stand, to work satisfactorily, should be right or left, having the middle lever-rest slightly to the right or left of the midway position, according to the same rule just cited for the crank.

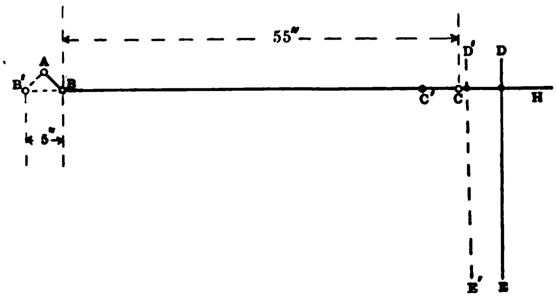


Fig. 109.

A stand having the middle lever-rest 90 deg. from the other two rests or a stand not having the crank of the shaft just exactly the right length for the throw desired, can be made to satisfactorily operate a three-throw or a two-throw switch by setting it slightly skewed on the headblock. The position can be easily found by trial. It will readily occur to anyone that by slightly turning the stand about the axis of the shaft the perpendicular distance from the switch rail to crank-pin will be changed for the middle lever-rest but practically not for the lever in the two extreme rests, since as the stand is skewed around through a small angle either way the crank pin in either of these positions moves parallel to the track. This slight skewing of the stand presents a rather unsightly appearance, when observing it from near by, but it permits of a more satisfactory throw to the rails and it may not seriously interfere with the service of the target; if it does, the target may be moved around slightly. All switch stands for the main track on the same road should throw alike—that is, to avoid confusion, they should all throw either in the same direction as the movement of the switch rails or all in the opposite direction to such movement. The feature of design which determines this matter is whether the lever and crank are both on the same side of the shaft or on opposite sides of the same.

Locating and Setting.—The location of the switch stand on single track is a matter of some importance and has been discussed a good deal.

For convenience of train operation the stand should be on the engineer's side when approaching the switch in the facing direction, as then it is seen to best advantage when "flying in" cars. For stub switches this is undoubtedly the better arrangement, but for split switches the safest arrangement is to put the stand on the turnout side of the track. The explanation in the latter case is that with the stand on the turnout or frog side the connecting rod when holding the switch points to the main-track position is in a state of tension, and any bending of this rod by derailed wheels or dragging parts of cars only pulls the points against the stock rail more firmly. If, however, the stand was on the opposite side, the connecting rod for the same position of the switch would be in compression, and any bending of the same would shorten the rod and tend to open the points. It is also probably true that with two or more switches close together trainmen are not so liable to throw the wrong switch when the stands are arranged in this manner. In some cases, however, it might be advisable to disregard these rules, in order to give the engineer the best view of the stand when approaching the switch; as, for instance, where the switch is so located that the trains must approach it around a curve in a cut, or where the view is obstructed by trees or buildings, in which case the stand would usually be seen to best advantage by placing it on the same side as the outside of the curve. On double tracks at usual distances between centers it is of course necessary to put switch stands of ordinary hight on the outside, and as this is the engineer's side (except in the case of left-hand running) it is, for another good reason, the better arrangement. The stand for a switch on the middle one of three tracks is sometimes placed on the outside and connected by means of a long rod extending across the intervening track, between the ties; otherwise, or if placed between the tracks, a low stand or ground lever must be used.

The stand should be set a good distance clear of the track, so as to avoid being knocked down by a derailed car running out of line. Six feet from the rail is considered a safe distance. Where there are two or more stands near each other on the same side of straight track the shafts and connecting rods should be of variable lengths (by about 2 ft.), so that both targets or both switch lights may be seen distinctly by an engineer approaching the switch. On double track it is well to place the lowest stand in the advance. At switches the roadbed or ballast on the stand side should be graded level with the tops of the ties sufficiently wide for a runway, which should extend about 100 ft. each way from the headblock.

Switch stands should be secured to the headblock by lag screws or by bolts passed up through from below, so that the nuts will be on top where they may be seen. The holes through the base or foot flanges of the stand should be drilled or reamed out so that the lag screws or bolts fit snugly. The way to set a stand properly is to connect it to the switch rails set for main track, square it with the headblock and tack spikes around the sides of the base to hold it temporarily, so that it may be thrown for trial. If lost motion is found it should be taken out before permanently securing the stand. When the stand throws properly for both main track and turnout the position of the bolt holes in the base may be marked, the holes may be bored and the stand bolted fast. In resetting a stand the old bolt or spike holes should be plugged and new holes should be bored. The best plan, however, is to pull the spikes from the headshoes and shift the headblock 2 or 3 ins. lengthwise, so as to get clear of the old holes. A switch stand designed by Mr. A. A. Robinson while chief engineer of the Atchison, Topeka & Santa Fe Ry., has a commendable feature in the shape of depending flanges at the sides of the base, which fit over the edges of the headblock and hold the stand square with the block. Wherever it is practicable to do so, the stand should be so set that when it is turned for main track the crank will stand perpendicular to the direction of the track. In this way the sidewise pressure from the moving rails bears directly against the shaft and its bearings, where otherwise it would operate to revolve the crank. This is called setting the stand "the strong way for the main line" and the arrangement is of importance, since it saves much wear to the parts of the stand by lessening the tendency of the shaft to being revolved by the jarring of passing trains.

Safety Arrangements.—One danger ever present with the switch which has but a single connection with the stand is the liability of the breaking of the connecting rod or the breaking of a bolt in one of the connections of the rod, in which event the jarring effect of a passing train would very likely open the switch. In the case of a switch on straight track, with proper connections carefully attended to, the risk is not great, but on curves the connecting rod of stub switches should not be depended upon to hold the moving rails to place, especially where the throw is toward the outside of the curve; for by reason of the necessary absence of spikes along the moving rails the outward pressure against the rod is consid-

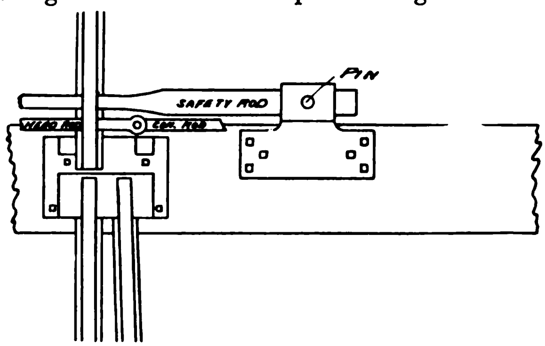


Fig. 110.—Stop Device for Stub Switch.

erable. A stop device frequently used to relieve the connecting rod consists of a switch rod extended a short distance beyond the rail on the stand side, the portion of the rod outside the rail being flattened to slide through a slot in a cast or forged block made fast to the headblock. The stop is effected by a hole and pin, as shown in Fig. 110, the hole in the block coming even with that in the rod for the main-track position of the switch. There should be only one hole in the rod. A latch arrangement used on the Canadian Pacific road consists of a flat notched rod sliding through a block similarly to the one just described. There is a notch in the block even with that in the rod when the switch is set for main track, and in this notch rests a weighted foot lever pivoted to the headblock. It is perhaps more convenient than the rod and pin arrangement. It is the practice with some roads to use a stop or safety attachment on all stub switches. It is questionable, however, whether any device requiring extra manipulation in throwing or locking the switch is to be recommended further than for switches from curves. They are necessarily the cause of some delay in throwing the switch, from which results an occasional blunder and derailment when "flying in" cars. Nevertheless mistakes of this kind cannot offset the security which such appliances afford to fast trains at switches from curves.

With the Flickinger ground-lever switch stand, which is used with both stub and split switches, the safety attachment, although independent of the connecting rod, is operated by the action of the switch stand itself, so that no extra attention need be given to the safety or stop device. Referring to Fig. 111, the barrel or cylinder *A-A* is provided with a screw and turns within the larger cylinder *B*, the latter being provided with a suitable female thread. The pitch of the screw is such that a half revolution (a complete throw of the lever from one side to the other) moves the cylinder a distance corresponding to the throw of the switch. The switch target is placed upon a vertical shaft housed in the frame of the stand, or cylinder *B*, and is revolved by the action of a crank on the cylinder *A*. For use in yards the lever is thrown into latched rests and the mechanism as thus far described constitutes all of the necessary parts of the stand. For use on main line there is an extra piece, marked "safety rod" in the figure, which is attached to the switch rail and slides underneath the stand in coincidence with the movement of the cylinder *A*. The safety rod is adjustable and the pivotal end of the lever is provided with an arm on either side which fits into a

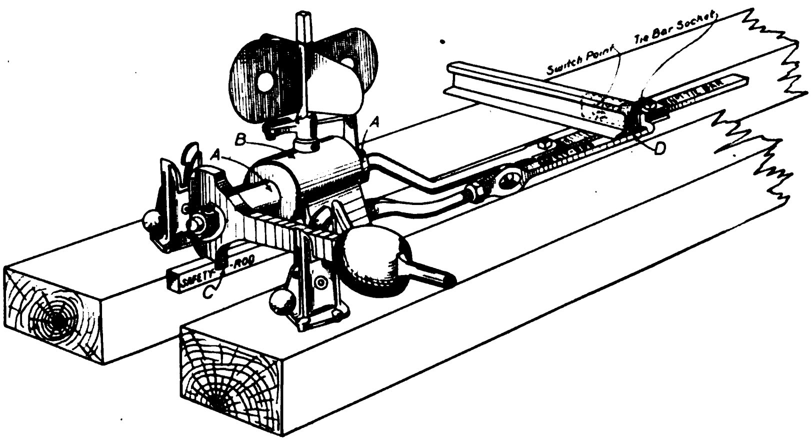


Fig. 111.—Flickinger Switch Stand, L. S. & M. S. Ry.

notch in the safety rod at *C* when the lever is thrown down into its rest. This arrangement insures the holding of the switch rails in their closed position in case the connecting rod should break or become disconnected. This stand is in use on the Lake Shore & Michigan Southern, the Pittsburg & Lake Erie and other roads, on both main line switches and in yards.

Where there is only one connection or means for holding the switch to the main-line position extra precaution is necessary to guard against the accidental disengagement of the connecting rod from the stand or the switch rails. The bolt through the connecting rod and head rod connection should be passed up from below and the nut should be secured with a cotter pin or jamb nuts, or the thread should be ruptured outside the nut. In addition to this a piece of tie or block of suitable size should be embedded in the ballast close under the rod, extending under the range of movement of the bolt, so as to prevent it from dropping out in case it should break or the nut become loose. Whenever the headblock is to be tamped this piece of tie must be taken out, but it can be put back without much trouble. It is considered safer practice, however, to have the connecting rod join directly with the switch rail instead of the head switch rod, as then one connection is avoided and there is one less joint for the development of lost motion. This can be done by using

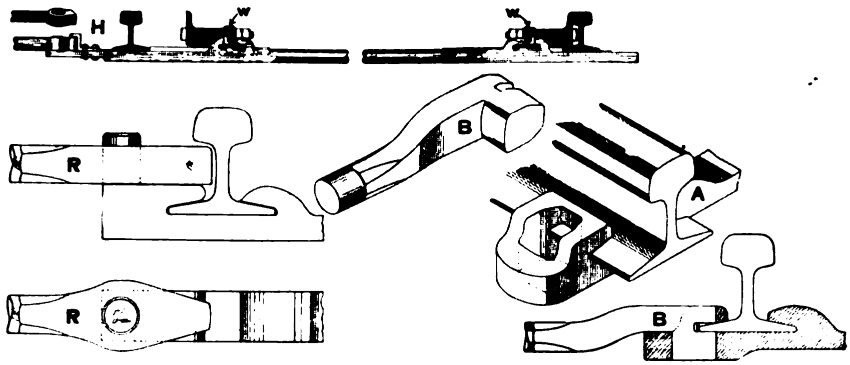


Fig. 112.—Switch Rail Safety Connections—Fig. 113.

a connecting rod which gripes the flange of the rail after the manner of an ordinary switch rod; as does Bar *D*, Fig. 105, or Connecting Rod *A*, Fig. 118. Figure 112 (*R*) shows a head rod connection for stub switches adopted at an early day by the Atchison, Topeka & Santa Fe Ry. and later by the Southern Pacific road. The head rod has a 1½-in. pin projecting upward near its end (Bar *C*, Fig. 105) and the connecting rod is extended to pass under the head of the rail. With the head rod in place the connecting rod must be swung parallel with the rail in order to be connected with, or disconnected from, the former; the connection cannot be broken, therefore, so long as the connecting rod remains attached to the stand. The Elliot company has a similar arrangement known as the "safety end" head rod. As shown in Engraving *H*, Fig. 112, there is a large pin near the end of the head rod, with a "safety clip" to hold the connecting rod from disengagement except when swung parallel with the track.

Figure 113 (*B*) shows another safety connection, used also on the Southern Pacific road. Rods *A* and *B* are locked together and slipped over the end of the rail, from which neither can become detached without reversing the process. Still another arrangement for dispensing with the use of a bolt at the connection between the head rod of a switch and the rod connecting with the switch stand is in use on the Gulf, Colorado & Santa Fe Ry. It was designed by Roadmaster M. O'Dowd and is

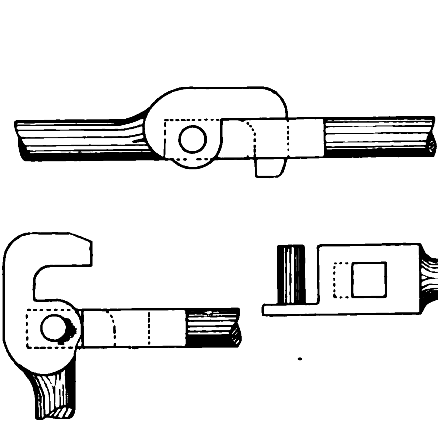


Fig. 114.—O'Dowd Switch Connection, G., C. & S. F. Ry.

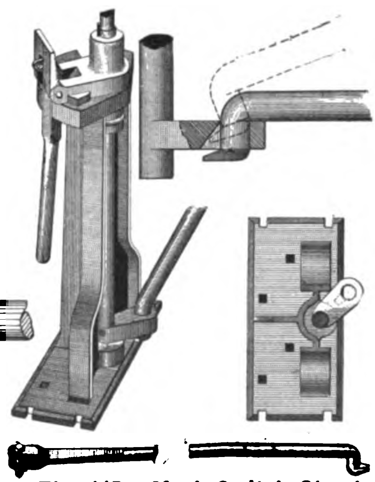


Fig. 115.—Mark Switch Stand.

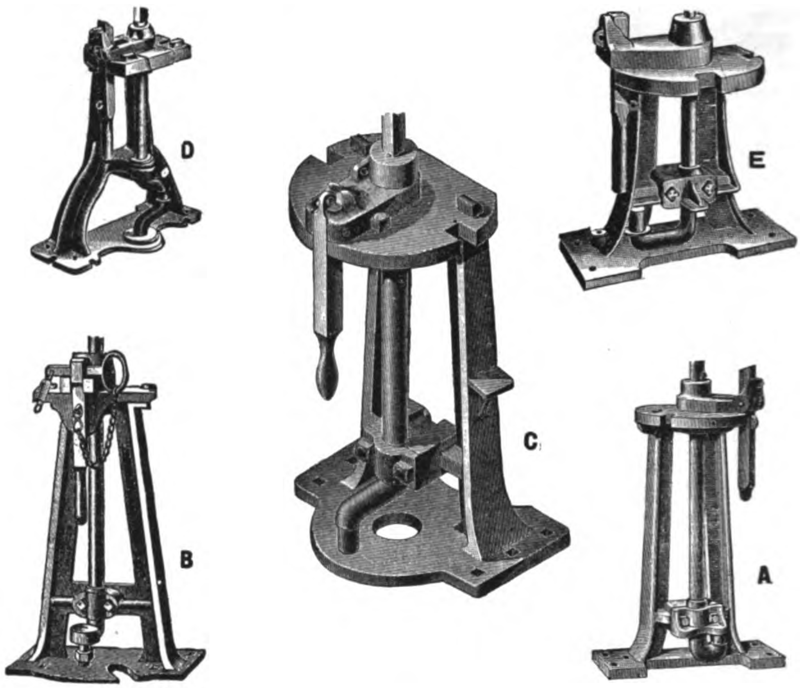


Fig. 116.—Safety Arrangements for Switch Stand Cranks.

used with split switches. Rod No. 1 of the switch, as shown by the lower engraving at the right in Fig. 114, terminates in a head which seats a pin, and through this head there is a rectangular hole. The rod connecting with the switch stand is hinged on this pin and terminates in a hook which enters the hole when the rod is swung to its normal position to be attached to the stand. The two parts thus become interlocked and the rod cannot be swung to the position of disengagement without taking the switch stand from the headblock. Longitudinal stress on the connection is taken by the hook, the pin acting merely to prevent the hook from slipping out of engagement. On some switches of the Baltimore & Ohio Southwestern R. R. the head rod is flat, standing edgewise vertically, and the end of the connecting rod is flattened to correspond, the two being connected by bolting together with two bolts. The connecting rod used with some of the vertical-lever switch stands of the harp pattern on the Baltimore & Ohio R. R. is one solid rod from switch stand to the farthest switch point rail, being fastened to the clips of the point rails and thus serving for both connecting rod and head switch rod.

If the crank pin projects upward, so that the weight of the connecting rod is carried by the crank, a key or cotter put through the pin and spread will secure the connecting rod; but if the pin hangs downward from the crank a key or cotter alone should not be depended upon to hold up the connecting rod. A strip of wood, fish plate or other device should be spiked across the headlock so as to project underneath the rod near the stand, for all positions of the rod, and thus make it impossible for the rod to drop down and become detached from the pin. With the foregoing points in view several of the manufacturing companies have designed stands with special reference to avoiding the use of pin, cotter or nut at the crank pin connection. In the Buda stand *B* and the Weir stand *C*, Fig. 116, the base of the stand is extended so as to embrace the range of motion of the crank. The crank pin hangs downward and meets this extension of the base, so that in stand *C* the rod cannot be disconnected without first taking the stand apart; in stand *B* a notch in the base will permit the rod to be dropped from the crank pin by bringing the crank over the notch and swinging either the stand or the rod around out of its normal position, without disturbing the shaft fastenings. The stand shown as Fig. 117 was got up on the same idea. It was designed in 1881 by the late Mr. W. G. Curtis, engineer maintenance of way of the Southern Pacific road, for use with the connecting rod shown as Fig. 113 (*B*). For an up-turned crank pin the Elliot and Buda stands *A* and *E*, respectively (Fig. 116), provide a "safety bottom cap" in the form of a projection from the lower housing of the shaft, said projection covering the crank pin in the "rest" positions of the crank. On stand *A* the rod can be detached by simply lifting it when the crank is thrown half way, but to do this with stand *E* the crank must be partially thrown and the housing disconnected. It will be noticed that in stands *A, C* and *E* the pin is formed by bending the end of the crank, the shaft, crank and pin constituting a single piece or forging—a simple and commendable arrangement. In stand *D* the shaft is bent into a double crank, to which the rod is attached by a strap connection, as is also the case with the Banner stand, Fig. 118. Rod *A* is used to connect with stub switches and rod *B* with point switches. The Whittemore switch stand (*S*, Fig. 119) is similarly designed respecting the crank and the connection with the same, and the crank and lever throw 180 deg. for a single movement of the switch. The corresponding quarter revolution of the target is effected by means of the gear wheels shown. The lever is attached direct to the crank shaft, or the one to which the smaller gear wheel is keyed. With the Mark switch

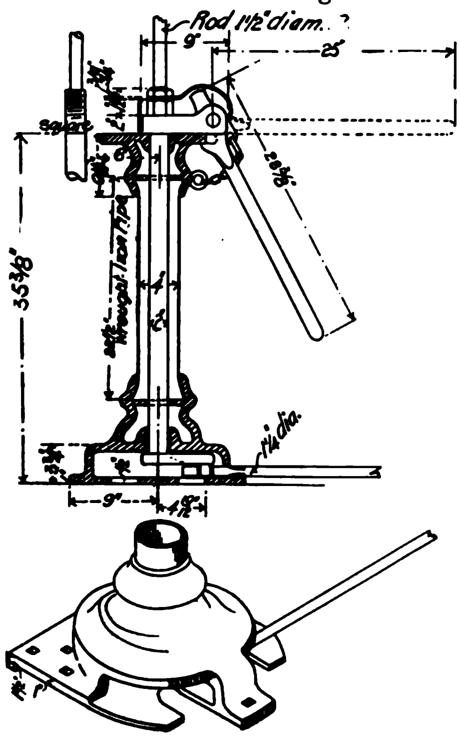


Fig. 117.—Switch Stand, S. P. Co.

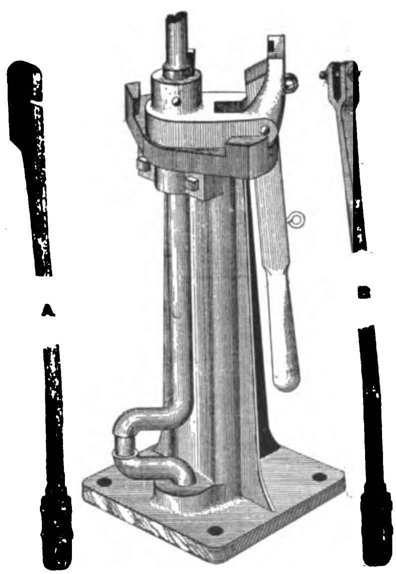


Fig. 118.—Banner Switch Stand.

Fig. 119.—Whittemore Switch Stand.

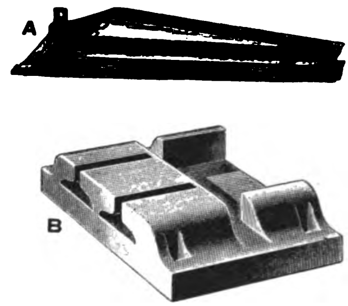


Fig. 120.—Ramapo Headshoe; Green Foot Guard.

stand (Fig. 115) the connecting rod cannot be detached from the stand without first disconnecting it from the switch; it must then be tilted, as shown by the dotted lines, in order to disengage it from the crank.

Targets.—Targets, or day signals used on switch stands to indicate the position of the switch, are arranged in many shapes, but in general they may be divided into three classes; namely, position targets, color targets and shape targets. By the first named term is meant a target formed by a single disc or sheet of metal or other device, which, by its position, indicates the position of the switch; by a color target is meant one having two target sheets or plates set at right angles, the position of the switch being indicated by the color displayed; and a shape target is one which indicates the position of the switch by the shape of the plate

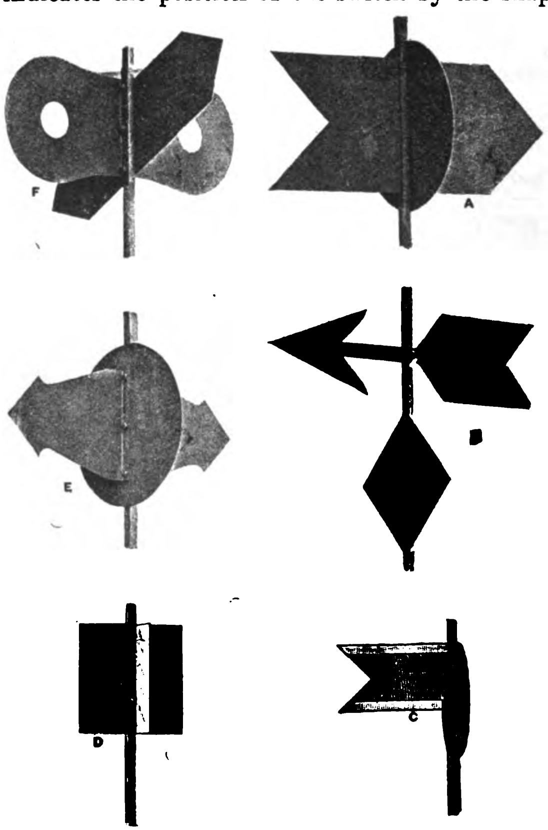


Fig. 121.—Switch Stand Targets.

facing the direction of the track. As a rule the two features of shape and color are combined. On a good many roads the preference is for a position target or signal, a simple form of which is a single piece of sheet metal (Fig. 123) set parallel with the track for the main-track position of the switch, so that it does not show in the direction of the track except when the switch is set for the turnout. This is commonly known as a "blind" target, or one which "shows its edge for safety." It is usually painted red, sometimes with a white trimming, although the color is obviously a secondary matter. There is seemingly only one objection against the use of this target, and that is that in case the target should become detached from the shaft there would be nothing in day time to indicate an open switch. If the target is properly riveted to the shaft this objection is not serious, because the probability of its being knocked or torn off and remaining unnoticed for any considerable time is remote, to say the

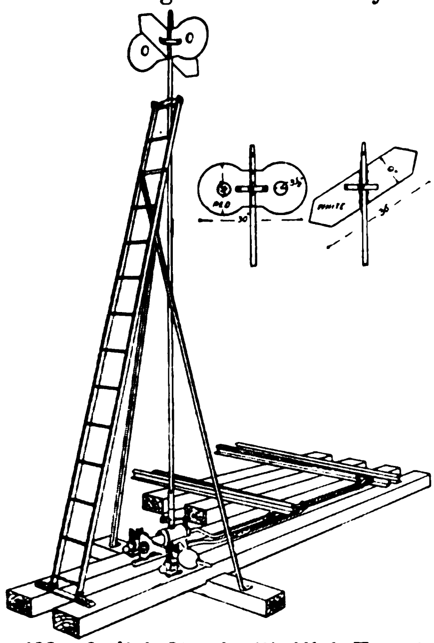


Fig. 122.—Switch Stand with High Target.

Fig. 123.—Elliot Snow Cap Stand.

worst, and, in any case, the same may be said of a target of any kind. Of course it is widely recognized as safe practice to regard the absence of a signal, where there ought to be one, as a danger indication, but as this rule presupposes that the engineman will be able to locate the switch and will bear it in mind before reaching it, the system cannot be considered faultless. As for a night indication there can be no question about the advisability of showing a light for each position of the switch, because it is not an unusual occurrence for switch lights to go out. The standard switch signal of the Chicago & Northwestern Ry. is of the blind target form, but the method of indication is peculiar in that the target shows blind for danger (open switch), or the reverse of ordinary practice. At night, however, the lamp shows green for safety and red for the open position of the switch.

Targets which show both ways should be composed of two entirely distinct shapes. Target *D*, Fig. 121, for instance, is a very undesirable form. During stormy weather or when smoke or steam is blown in front of a target, or at night, the shape is distinguishable more readily than the color. For this reason all the targets on any road ought to be of the same shape, and both position and color targets should not be used on the same road. The position target gives the safer indication at night, and if the switch light has gone out it is at least of some service. Another idea in shape targets is to separate the sign plates for the two indications, as in Engraving *B*, Fig. 121. The standard switch target of the Union Pacific R. R. is a rectangular white plate with a round red plate at right angles and underneath.

The Chicago, Burlington & Quincy and Cleveland, Cincinnati, Chicago & St. Louis ("Big Four") roads use a target having the white plate in the form of a comparatively narrow strip hung to the shaft at an angle of 45 deg. with the horizontal, in which position it somewhat resembles a semaphore arm set at clear. The red plate is set horizontally, or corresponding to the position of a semaphore arm set at danger. In one sense it might be termed a position signal. A target of this description is shown in Fig. 122. It is sometimes called the "semi-semaphore" target.

The target for a three-throw switch stand, where main track is the middle track, is sometimes made to point to the side toward which the switch is thrown. The fish-tail notched targets, *A* and *C*, and the arrow-shaped target *B*, Fig. 121, are examples of this kind. Stands should be set far enough from the track to have the target clear of trainmen hanging to the sides of cars; and, of course, the larger the target the greater must be the distance. Rivets are a more satisfactory fastening for securing the target to the shaft than are bolts, for bolts are the more liable to work loose, and even a slight looseness permits considerable swing in a thin metallic plate or sheet. On sharp curves, on double track, switch targets are sometimes set skewing to the track, so as to show to better advantage at a distance around the curve.

White for the closed position of the switch and bright red for the open position are the colors used almost universally for the targets of switch stands on main track. On double track the back of the white plate of a color target may be painted black or mud color, but for the security of "back-up" movements it is well to have the red plate show both ways. On blind targets there should be a disk or ring of white on the red, as the contrast shows off to good effect at night, red paint not being visible as such in dim light. It is important to have targets show plainly at night; for although switch lamps ought to be used (on all facing-point switches, without any question) they go out sometimes, especially where there is no night watchman or track-walker to care for them. To prevent confusion of signals to trains on main line it is to some extent the practice to avoid the use of red to indicate the open position of switches leading from side-tracks. In some cases of this kind green is substituted for red to show that the switch is open to the main side-track. On the standard switch stand of the Lake Shore & Michigan Southern Ry. the closed position of the switch is indicated by a circular target 16 ins. in diam., painted white for main line and green for side-tracks. The red target, showing the open position of the switch, is rectangular (16x24 ins.) for both main line and side-tracks.

To keep switch targets looking fresh and distinct in color they should be frequently painted. The rules of some roads require such painting to be done every six months or during the spring and fall of each year. A sheet of rusty iron does not readily catch the eye at a distance in cloudy weather. Targets are discolored by the greasy hands of lamp lighters and of brakemen who take hold of the target when throwing the switch. The appearance of the targets may be much improved, therefore, by washing them about once each month or two, when the paint may be made to appear nearly as fresh as when first put on. This practice of washing targets at intervals of a few weeks is in vogue on some roads. On a few roads, one of which is the Grand Trunk Ry., enameled switch targets have been used experimentally, the idea being that by cleaning them occasionally, repainting is unnecessary.

Dwarf and Ground-Lever Stands.—The most usual hight of switch stands for main track is 6½ to 8 ft. to top of target staff. When particularly designated, such is known as an "intermediate" stand. In yards, where the tracks are close together, there is not room for stands of intermediate hight, so that dwarf or pony stands (2½ to 4 ft. high to top of target) and ground or horizontal stands must be used. A dwarf switch stand extensively used in yards and side-tracks on the Denver & Rio Grande R. R. is designed with a yoke lying horizontally over the top of the stand casting or frame and keyed to the upright shaft. A circular red

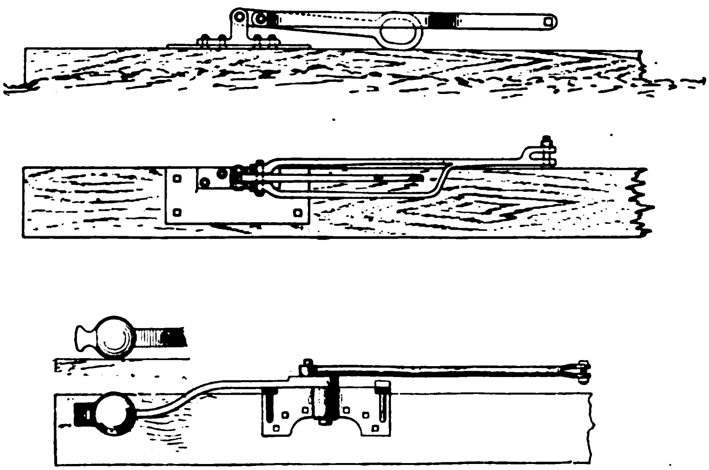


Fig. 124.—Ground-Lever Switch Stands.

target, to show the open position of the switch, is attached to each end of this yoke and hangs at the side of the stand. The arrangement thus provides a red target at each side of the stand, lower than the top of the stand casting and out of the way of poling. There is no target showing when the switch is closed, as when it is in that position the red targets show edgewise. Lights should be placed on dwarf stands to prevent trainmen from running into them in the dark.

In the less frequented parts of yards a simple ground-lever stand or tumbling lever is much used. One form has a heavy ball on the end of the lever (Fig. 124) so that the switch may be held in place without locking or latching. Such are commonly known as "drop-lever" stands. With ground levers weighted at the end it is not necessary to throw the lever as far as the dead center in order to hold the switch to place, and so for unusual pressure, as when point rails are trailed through, the stand will throw automatically, if not latched or locked. Figures 124, 125, 126 and 127 show other forms of ground-throw stands, those in the last two figures being for three-throw stub switches. With these stands either one of the double levers may be thrown to move the switch into the middle position, and then by throwing the other lever the switch is moved into the second position. By throwing both levers at the same time the switch may be moved from one extreme position to the opposite extremity. Figure 125 shows a ground lever equipped with a target and lamp rest, being low enough to permit the poling of freight cars over it when the lamp is on. For lack of room ground-lever or drop-lever stands are sometimes placed in the middle of the track, as in Fig. 135, being attached to the head switch rod by means of a short connecting rod. In this position the stand is not conveniently placed for flying in cars.

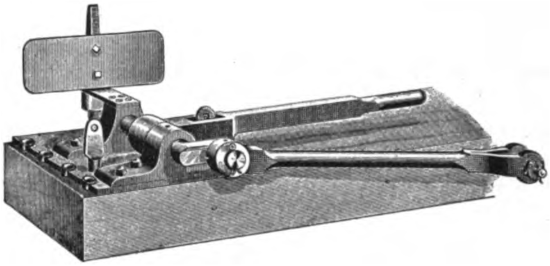


Fig. 125.—Ground-Lever Switch Stand with Target.

The standard switch stand of the Pennsylvania R. R., for both main track and sidings, is a simple ground lever attached to the switch points through a Lorenz spring on the head rod. Revolving stands are not used. On some of the divisions on the main line of this road the use of signals at trailing switches at outlying points and at stations where but little switching is done is dispensed with, there being neither targets nor switch lights. The practice of dispensing with switch lights and targets on trailing point switches on double track is also standard with the Pennsylvania Lines West.

By a bevel gear or other arrangement the levers of some ground stands are made to throw in a direction parallel with the track. They are the safer stand to use while cars are moving on an adjoining track, since the operator is in danger of being struck while handling a lever which throws crosswise between the tracks. The upper stand in Fig. 128 is of this kind. It is provided with a latch to hold the lever securely in the main-track position. The latch, shown in detail as Engraving *H*, Fig. 119, is weighted to swing over the lever. To release the lever the latch must be raised, which can be done either with the hand or the foot. A foot tripping device is shown on the latch illustrated with the "Low-Target Pattern" in Fig. 129A, and more in detail in Fig. 132A, the side of the casting in the latter case being broken to show the engagement of the foot trip with the latch. By means of a spring key inserted through a hole in the base casting the latch may be held out of engagement with the lever, permitting the stand to act automatically. For locking the

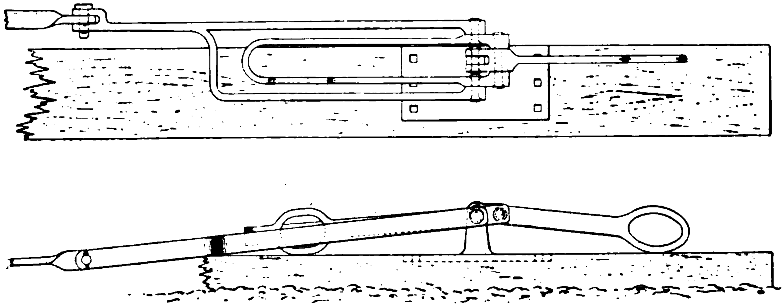


Fig. 126.—Three-Throw Ground-Lever Switch Stand.

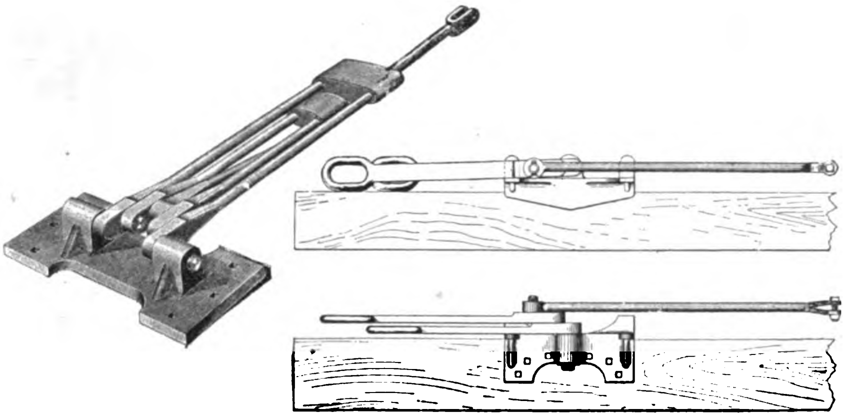


Fig. 127.—Three-Throw Ground-Lever Switch Stands.

switch there is a hole near the top of the latch in which a padlock may be used.

There are several patterns of parallel-throw ground stands working on the bevel-gear principle. Among the devices in service are the "Crown," the "Globe" and the "New Century" stands. The last named of these is illustrated in Fig. 129A. A semi-circular iron case encloses a bevel pinion on the axial shaft of a weighted lever, which engages with a bevel gear segment on the vertical crank spindle. The end of the weight on the lever has a deep recess providing a convenient hand hold for raising the lever. When not latched or locked the stand will permit automatic operation of the switch. The upper edge of the target stands 17 ins. above the tops of the ties. By means of a coupling shown in the engraving at the right of the figure, a target staff may be attached to the vertical spindle of the stand, supporting a target at the ordinary hight (about 7 ft. above the ties) for main-line service. On several of the southern rail-

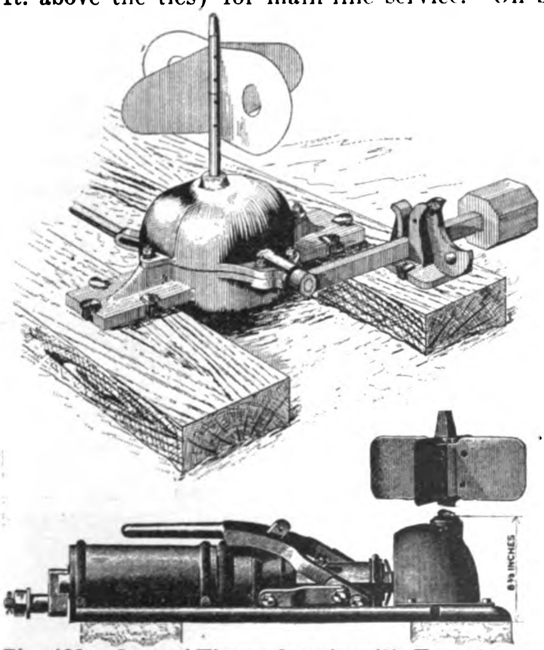


Fig. 128.—Ground-Throw Stands with Targets.

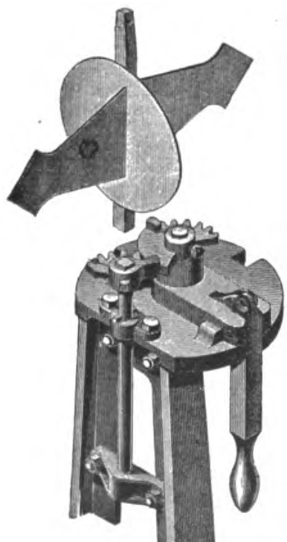
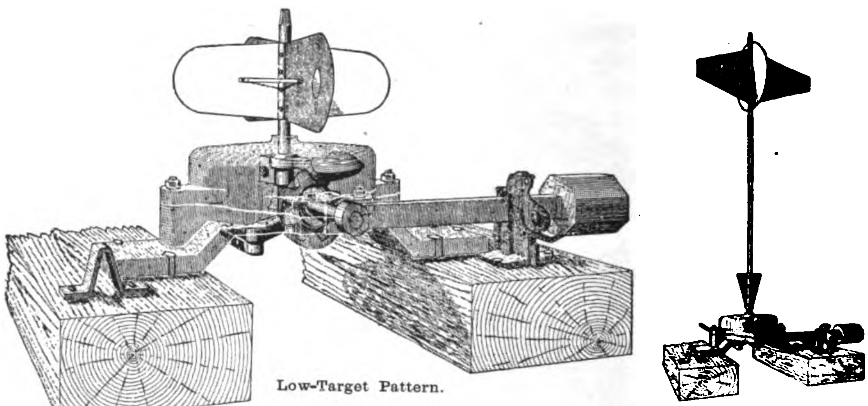


Fig. 129.



Seven-Ft. Target Pattern.

Fig. 129 A.—New Century Switch Stand.

roads this "7-ft target pattern" is the standard for main-line switches. The side projecting flanges of the coupling serve for a step when placing the lamp in position.

Another parallel-throw ground stand with low revolving target is the Odenkirk pattern, in use on the Pennsylvania and the New York, Chicago & St. Louis ("Nickel Plate") roads. Referring to Fig. 130, the base or main casting which forms a box enclosing the working parts is cylindrical, and within this cylinder a so-called cam *C* revolves, the throwing lever being attached at the right-hand end of the shaft *S*. This cam is a round casting with a helicoidal groove 2 ins. wide running half way around on each side. A sliding rod *O* operates directly beneath the cam, the inner end of the rod carrying a pin *P*, upon which revolves the roller *R*. As the cam is turned over by the lever this roller follows the groove, moving the sliding rod to and fro. The connecting rod running to the switch rails is joined onto the sliding rod by the bolt *T*. The distance *A-B* is the throw of the switch. The mechanism is simple and includes no gears. The roller is case-hardened and is supposed to stand the wear very well, operate easily and with practically no lost motion. The banner signal is revolved by means of a small crank at the lower end of its shaft, the crank being moved by a projection on the sliding bar *O*. All these parts are tightly enclosed within the base casting and are free from dust, snow and ice. They are accessible by removing the cover plate *L* from the end of the base casting by taking off the three nuts shown in the figure. The same stand with a low sema-

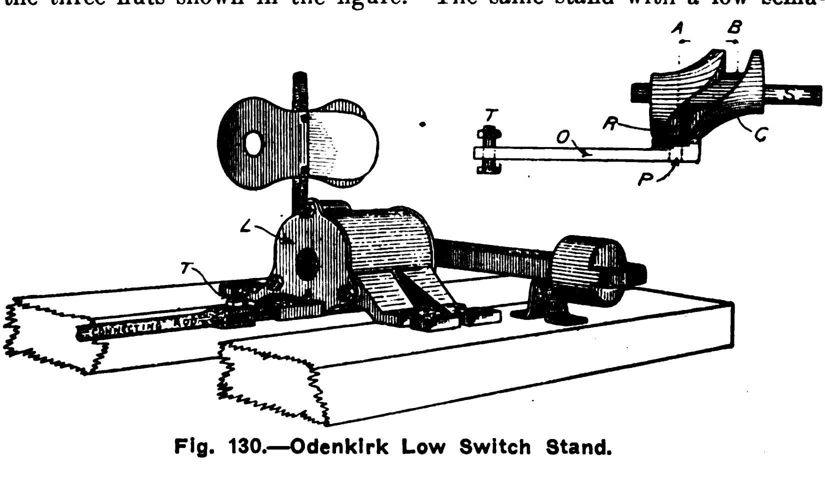


Fig. 130.—Odenkirk Low Switch Stand.

phore arm is shown as Fig. 131. By a slight modification in the shape of the cam and the omission of a lock or latch the stand is made to throw automatically when the switch is "run through." The lower stand in Fig. 128 is the Ramapo pattern, the automatic feature of which is explained farther along. The lever of this stand, after being lifted from its rest, is thrown in a direction crosswise the track. In point of construction it is essentially a vertical stand laid horizontally.

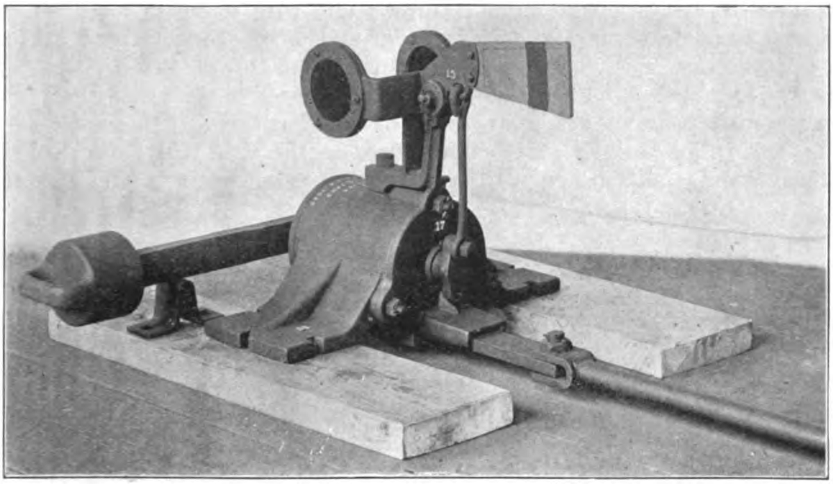


Fig. 131.—Odenkirk Switch Stand with Low Semaphore.

Another style of low switch stand operating on the cam principle consists principally of a drum and slot. The Stoney drum switch stand, designed by Chief Engineer E. W. Stoney, of the Madras Ry. (India), and extensively used on that road, is shown as Fig. 132. This device comprises a cast-iron cylinder or barrel which turns on an axle fixed in a suitable casting, being actuated by a weighted lever handle centered on the same axle, and passing through a short slot in the drum. The switch is moved direct by a roller on a pin fixed to the connecting rod. This roller fits in, and is driven by, a spiral slot S in the drum. The handle requires only a light weight to

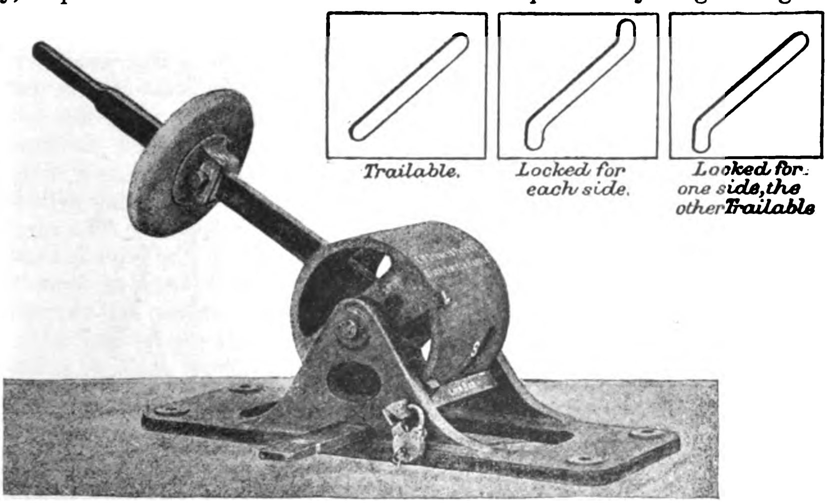


Fig. 132.—Stoney Drum Switch Stand.

hold the points and works easily. It is made either trailable, or, by simply turning the lever over, to lock the switch dead to one or both sides, or so that it shall be locked for one side and trailable for the other. This arrangement is effected by simply altering the shape of the slot in the drum which actuates the connecting rod, as explained by the line engravings in the figure and the accompanying legends. The drum may be further locked, so as not to be moved, by a simple sliding locking bar secured by a padlock, as shown. In this country there are switch stands designed on the same principle. One of these devices is a Weir ground-throw stand with weighted lever, which, when not padlocked, is automatic, like one style of the Stoney stand, and, as is also the case with the Stoney stand, the lever throws parallel with the track. The Weir stand has a revolving target geared to the barrel shaft, and its general appearance is similar to that of the Weir three-throw switch stand Fig. 163. The Wrigley switch stand, used on the Erie R. R., has, like the Stoney stand, a slotted drum, which operates a balance lever attached to the

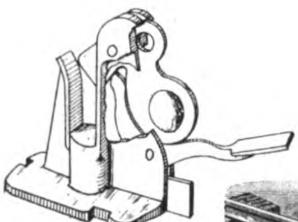


Fig. 132 A.

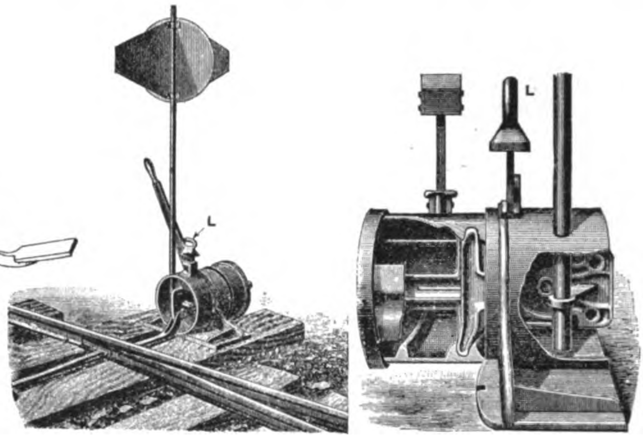


Fig. 132 B.—Monitor Switch Stand, Hocking Valley Ry.

switch connecting rod. It can be made to throw automatically in one or both directions. It has a revolving target 17 ins. above the tie face and has an attachment for working a detector bar, if desired.

The Monitor switch stand, which has been standard with the Hocking Valley and the Baltimore & Ohio Southwestern roads a long time, works on the principle of a screw. The stand and parts are shown in Fig. 132B. The frame of the stand consists of a base plate and cylinder cast in one piece. This stationary cylinder is grooved to receive the end of a revolving cylinder. The revolving cylinder is closed at the outer end, and through a slot in a head or partition of the stationary cylinder there is a sliding bar worked by a disk fitting a screw on the inside of the revolving cylinder. This sliding bar is coupled to the connecting rod of the switch. The revolving cylinder is provided with a socket for a lever, and as the lever is turned the sliding bar is actuated by the screw and moves toward or from the track in a straight line. There are no springs or gear wheels, and the working parts are completely housed from snow and ice. It can be used with or without a staff and target. For yard service the revolving cylinder is fitted with a weighted drop lever, which will permit the stand to throw automatically if the switch points are trailed when wrongly set. For main-track service there is a hand latch (L) which drops automatically into a notch in the sliding bar as soon as the switch is thrown home. This latch relieves the screw mechanism of all strain from passing trains. In throwing the switch it is necessary to first lift the latch from its seat. The stand is locked by securing the latch with a padlock at a notch in the latch sleeve. If the stand is to be used for an automatic trailing switch for main line it should not latch when thrown for the siding. In that case a weighted drop lever is used to hold the switch in position. The target shaft fits the socket of the shifting arm in a square hole, and if, in setting the stand, the colors of the target are not right, it is only necessary to raise the staff out of the socket and give it a quarter turn.

For three-throw switches, where the main line is the middle track, an ordinary stand throwing 180 deg. will answer, because by setting the target to show safety for the middle position it or the switch light will show danger when the stand is turned for either of the other tracks. By a specially arranged target the signal will indicate in daytime to which of the two side-tracks the switch is set. As already shown, the target is sometimes made arrow-shaped, so as to point toward the side on which the switch is set. The necessity for arranging the target to indicate the position of the switch, however, is not as great as a corresponding arrangement for the switch light, for on straight track the position of the switch may easily be seen a considerable distance in daytime, whereas such is not the case at night. The photographic view in Fig. 134A shows an arrangement used by the Duluth South Shore & Atlantic Ry. to indicate the position of a three-throw switch at night. The switch is of the stub pattern, and the switch stand is of ordinary construction, with the top table notched for three positions of the lever. The target is of the ordinary pattern which shows a disc when the switch is set for main track and blind when the switch is set for either siding. Bolted to one side of the switch stand there is an upright frame (*BB*) carrying at the top a rectan-

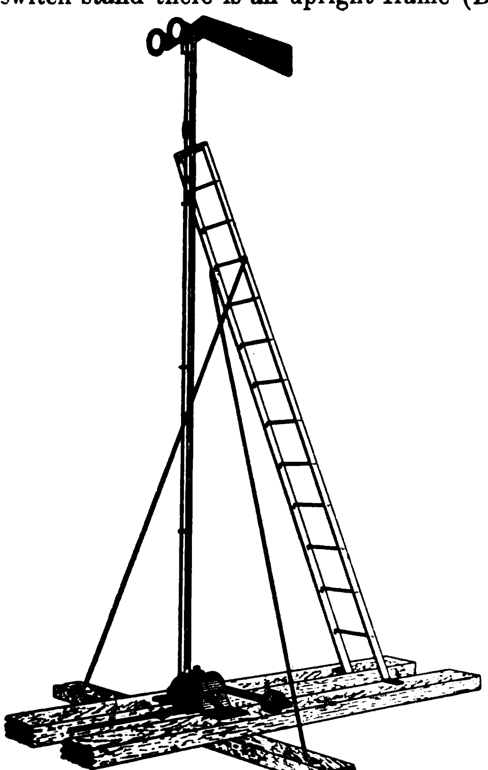


Fig. 133.—Ground-Throw Stand and High Semaphore.

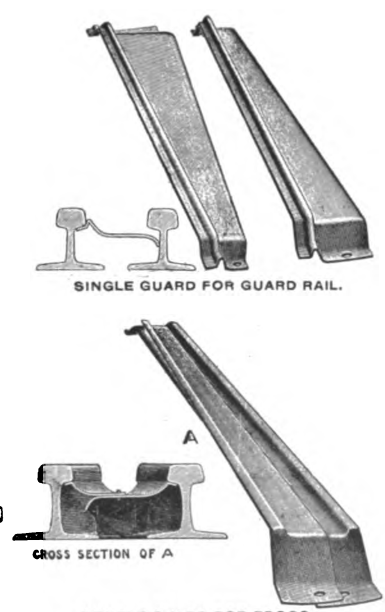
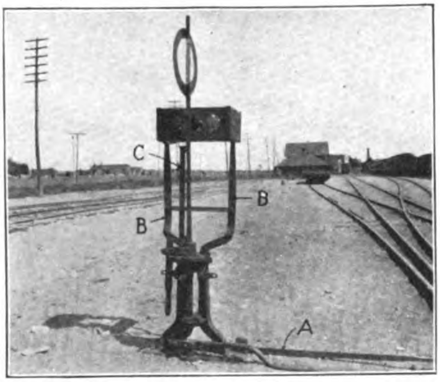


Fig. 134.—Sheffield Foot Guard.



Signal Lights for a Three-Throw Switch, D., S. S. & A. Ry.

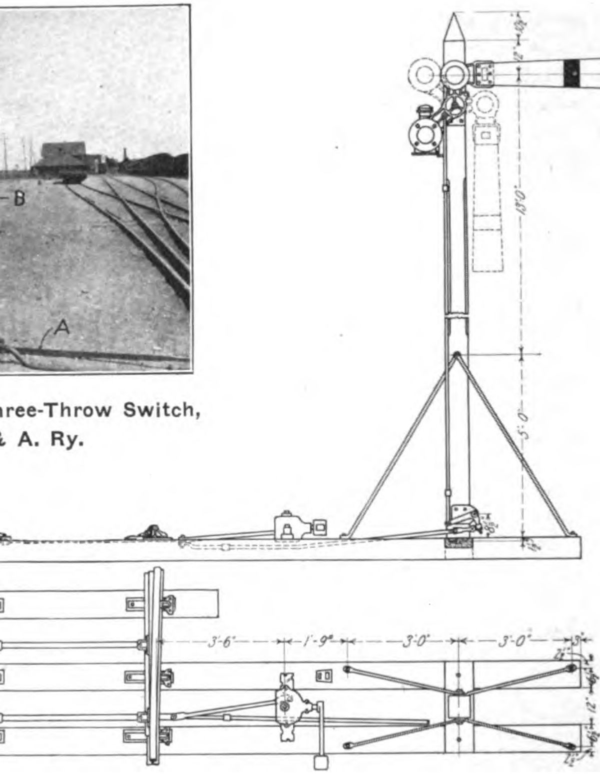


Fig. 134 A.—High Semaphore Switch Signal, Pennsylvania Lines West.

gular wooden box open top and bottom. In two sides of this box there are three lenses in a row, the colors from left to right (as seen in the picture) being red, green and white. Attached to the moving rails of the switch there is a rod (*A*) sliding through a guide at the bottom of the switch stand and bent to stand in an upright position (*C*). This upright rod (*C*) carries the switch light inside of the box. In any of the set positions of the switch this light shines through one of the bull's-eyes and indicates by the color of the light the position of the switch. For instance, if the switch is set for the main track the light will shine through the middle or green bull's-eye, giving a green light. If the switch is set for the left-hand siding there will be a red light, and if it is set for the right-hand siding there will be a white light.

When both turnouts are on the same side of the main track an ordinary stand thrown to the first shows danger but when thrown to the second it shows safety. For a switch of this kind a stand having a specially arranged target-revolving device is required, so that danger will be shown when the stand is thrown for either turnout. There is a Weir stand of this kind having the target arranged upon a separate shaft, which is so geared with the main shaft of the stand (see Fig. 129) that when turned from the main track position to that for the first turnout it is thrown out of gear and locked fast against further turning when throwing the stand for the other turnout. When thrown back to main track the gears engage, as the idle quarter of the driving gear is passed, and the target revolves back to safety. Stands for three-throw point switches and automatic stands for point switches are taken up in connection with those subjects, further along in this chapter (§ 71 and 68).

High Targets.—The question of safety for high-speed trains has led some roads into the use of high switch targets that may be seen over the tops of cars, over shallow cuts in curves, or other obstruction; or at a long distance on straight line. The usual arrangement consists of a ground-lever stand connected to a braced target rod or shaft 12 to 18 ft. high. The target shaft is braced by an inclined ladder running from the end of a long headblock and stayed sidewise by angle irons or pipes footing into a cross piece framed into the headblock, as shown in Figs. 122 and 133. On some roads the target is set on a collared shaft resting in bearings on a post or framing independent of the stand, so as to be free from the jarring, which might put out the switch light. The shaft is then connected with the switch rails or to the stand. The ground-lever type of stand used in connection with a high signal is coming more and more into use, and is standard on the Southern Ry., the Pennsylvania Lines West, the Cleveland, Cincinnati, Chicago & St. Louis and other roads. On the Southern Ry. the standard arrangement for throwing and signaling switches is a New Century switch stand with a large revolving target on a staff about 17 ft. high, braced with ladder and stay rods as in Fig. 122. On the P. L. W. the standard switch signal at high-speed points is a semaphore blade 18 ft. high on a wooden pole standing 8½ ft. from the rail, at the switch. A parallel-throw ground-lever stand is connected with both switch and signal, as shown in Fig. 134A. A similar or like arrangement is also in use on the Peoria & Eastern division of the C., C., C. & St. L. Ry. Under dangerous conditions the P. L. W. use a distant switch signal in addition to the semaphore at the switch (See also §213, Suppl. Notes).

Switch Locks.—The almost universal arrangement for locking switches is to padlock the lever of the stand. Numerous devices have been invented to dispense with padlocks on switch stands and the extra movements attending the use of the same when locking or unlocking the stand, but such have never come into extensive service. There are, however, in practical use a few patterns of switch stand designed with a self-contained lock. A number of stands of this description have been in use on the Burlington & Missouri R. R. since 1896, giving satisfactory service. The stand was designed by Mr. T. E. Calvert, general superintendent, and in addition to the permanently attached lock it is also arranged to permit the automatic operation of the switch when the stand is set in either of the rest positions. Referring to Fig. 134B, there is a hollow lever *S*, one end of which encircles the main shaft of the stand without being rigidly attached. At the outer end of this lever there is hinged a handle *M*, which normally drops to a vertical position into a notch in the outer rim of the stand table *R*. Rigidly attached to the main shaft *T* by means of a bolt and key there is a star-shaped interlocking head or pinion *N*, and fitting tightly into one of the recesses of this head is an interlocking bolt *L* with an arrow-shaped head. At the other end this bolt terminates in a stud, as shown in the perspective view, Sketch 9. A coiled spring holds the head of the bolt into engagement with the interlocking head under all conditions. The lock *P*, Sketch 1, is in an opening in the side of the lever, being slipped into place from the inside before the interlocking bolt and spring are inserted. It is then held in place by a coiled spring. When the handle *M* is in the normal position the bolt *Y* of the lock, Sketch 5, fits into a slot in the head of the handle made by cutting away on one side of the radial opening *m*. A perspective view of the handle and the locking slot is shown as Sketch 8. In this manner the handle is locked in position. After the key has been inserted, the locking bolt *Y* pulled back and the handle raised, the solid face of the circular head on the handle holds the lock bolt back (Sketch 6) and the key cannot be turned to be withdrawn until the switch has been moved to such position that the handle may again be dropped to its normal position; so that the handle must be in the rest notch at one side of the table, and in normal position, before the key can be removed. Where it is desired that the key may be withdrawn only when the switch is set and locked for main line, a small bolt *W* is screwed into the rest notch at the side-track side of the table (Sketch 7), so as to prevent the handle *M* from dropping to normal position on that side, and make it impossible to withdraw the key when the switch is set for side-track. This arrangement necessitates throwing the handle back to the main-track side and the locking of the stand before the key can be removed.

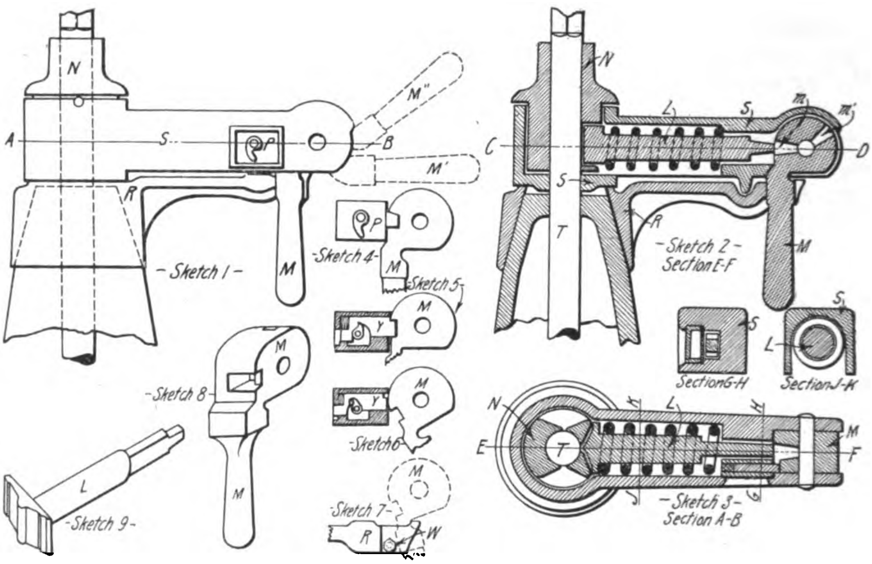


Fig. 134 B—Automatic Switch Stand with Self-Contained Lock, B. & M. R. R. R.

Another aim in getting up the design was to make a stand which would be automatic when thrown and locked, but rigidly connected while being thrown, so that if snow or other obstruction should prevent the switch point from closing against the stock rail the switch stand lever could not be thrown into the rest position and locked. As a means to this end, the head of the handle *M* when raised to the horizontal position, as shown in Sketch 1 at *M′*, bears tightly against the interlocking bolt, holding the same into rigid engagement with the interlocking head *N*, so that while the switch is being thrown this bolt is prevented from any backward movement and the shaft *T* cannot revolve except with the lever. In the head of the handle *M* there is a radial opening *m* (Sketch 2), and when the handle is dropped to the vertical or normal position this opening stands opposite the stud end of the interlocking bolt *L*, permitting the bolt to recede from its normal position in case sufficient force should be applied to the crank of the stand to revolve the interlocking head against the action of the interlocking bolt and spring. Thus the stand is rigidly connected while being thrown and automatic when locked. For automatic operation the tips of the interlocking bolt are so shaped that during the first part of the automatic action the switch starts hard. The movement then becomes easier until the center of the throw is reached, when a rib at the extreme end of the bolt again resists the throwing action until considerable force is applied. If the switch is moved past the center the pressure of the spring on the bolt will quickly force around the interlocking head and complete the throw of the switch, but if pressure on the switch points is released before the center point is passed the action of the spring on the interlocking bolt will operate to quickly throw the switch back to place. Thus, should a car or locomotive trail against the switch points when set in the wrong position, without running through them far enough to throw the tip of the interlocking head past the dead center, the points will be returned to place against the stock rail as soon as the train backs away. It will be noticed that the interlocking head has three recesses (Sketch 3), two of which are disposed at right angles to the one shown in engagement with the interlocking bolt. This arrangement allows the shaft to be turned a quarter of a revolution in relation to the interlocking bolt, thus permitting the throw of the stand to be changed from right to left, or vice versa, without changing the position of the stand. In order to return the interlocking bolt *L* to its proper recess in the head *N* after the switch has been "run through" and thrown automatically, there is a second radial opening *m'* in the head of the handle *M*, Sketch 2. By turning the handle up to the position *M''* (Sketch 1) this opening is brought opposite the stud end of the interlocking bolt *L*, permitting the bolt to recede and the lever to be swung around on the interlocking head, thus bringing the interlocking bolt and head again into their customary relative position.

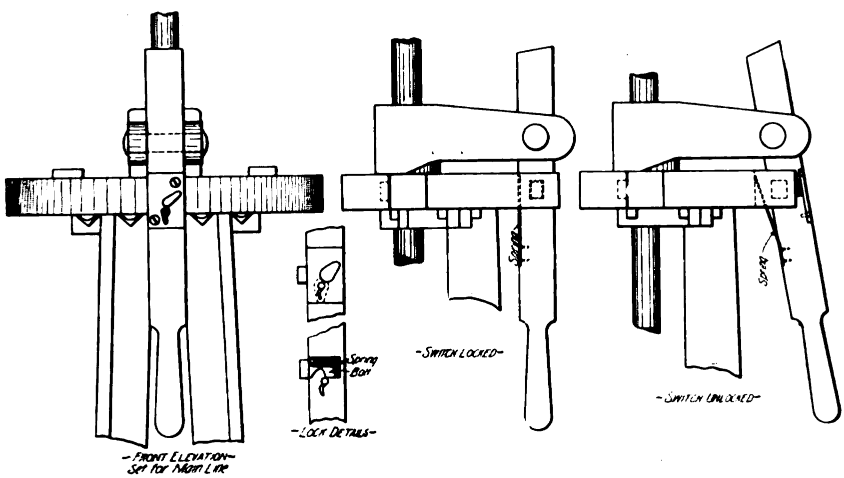


Fig. 134 C.—Cafferty-Knox Lever Lock for Switch Stand.

The Automatic Safety Lock switch stand has, like the one already described; an enclosed lock within the lever of the stand. This stand, with its lever, latch and cap are shown by the three engravings in Fig. 136. A vertical cover actuated by a coiled spring affords protection to the keyhole. This cover moves directly upward between guides, thus making it possible for trainmen to introduce the key, unlock and throw the switch with one hand, as at night, when carrying a lantern. The lever is released by pulling the safety latch, after unlocking the stand with the key. Engravings *A* and *B* show the two positions in which the latch may be set. The latch catches in one position (Engr. *A*) before the locking bolt comes into action, and in that position it secures the switch without locking the stand. This arrangement is for convenience when shifting cars. Permanent locking is effected by compressing the latch and throwing the lever up against the shoulders of the locking stud, whereupon the locking bolt falls and the switch cannot then be thrown without the use of the key. The stand in the locked position is shown by Engr. *B*. It is used on the Mexican International and some other roads.

The Cafferty-Knox lever lock for switch stands, designed by Mr. T. S. Cafferty, roadmaster with the Atchison, Topeka and Santa Fe Ry., and Mr. Wm. F. Knox, is a simple locking mechanism consisting of an ordinary spring bolt lock, placed within the switch stand lever and engaging with a lock notch cut into the side of the lever rest in the table of the stand. As the lever locks automatically when closed into the rest notch, a spring is provided which holds the lever outward to prevent it from locking when it is not pressed home, or as it would be left while switching. The lock is applied to the lever by planing or filing out a recess in the front side and covering the same with a plate screwed on. It can be applied to any drop-lever stand that works in the ordinary manner. It is

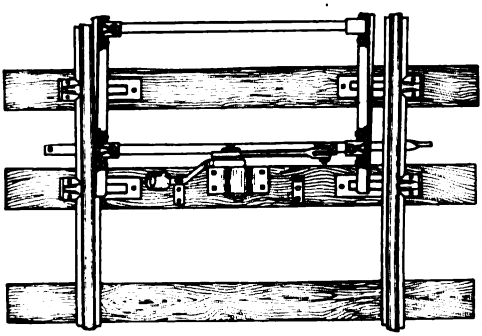


Fig. 135.—Ground-Lever Stand in Track.

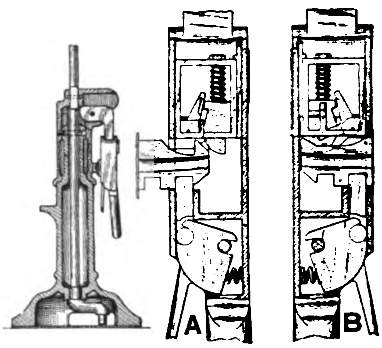


Fig. 136.—Automatic Safety Lock Switch Stand.

not necessary that a new handle be used, as the lock can be placed in the old handle equally as well as in a new one, after which all that is necessary to do is to chip a notch in the top plate of the stand to receive the bolt from the lock. Figure 134C shows the lock as applied to a stand of ordinary pattern. The engraving at the left shows the position of the keyhole in the front of the lever, and the small engraving shows the lock details. The engraving at the right of the figure shows the position of the parts when the switch is unlocked, with the lever still resting in its notch in the table, as it would be left while switching.

Advantages claimed for switch stands with enclosed locks, additional to those already indicated, are that the lock is boxed in out of the way, where it cannot be knocked off or easily tampered with by malicious persons; it cannot fall down into the mud or snow; and, what amounts to a matter of considerable economy, it can be used only for a switch lock. It cannot be used for locking a boat, a barn, a coal shed or other private property, whereon may usually be found no small percentage of the switch locks issued by railroads from time to time.

It is a good plan to lubricate the inside works of switch locks with a few drops of oil occasionally. With such treatment they will work easier and last longer. When locks get dry or rusty, so that the key turns hard, or if the parts become so worn that the key will not work the first time, the train men are quite likely to break them.

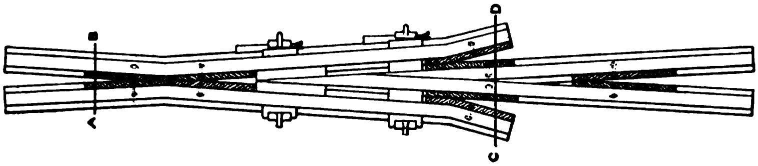
63. Headblocks.—Fifteen feet is the usual length for headblocks, and 8x14 ins. or 8x16 ins. about the proper size. Eight inches thickness gives good stiffness. It is difficult to properly tamp a headblock which is thicker than this; and for the same reason the adjoining ties each side of the headblock should not be too close. A good width is the best provision against settlement. Sawed headblocks are the better, but hewn ones do very well if the upper face is not winding. In laying a headblock the bed should not be dug out for it quite as deep as the combined thickness of headblock and headshoe under base of rail. It is better to leave it above ½ in. high, on a firm bed, after the headshoes are in place. Headblocks should be placed squarely across the main track and the joints between switch and lead rails should be exactly opposite. The headblock for point or split switches is often made double or of two pieces, each about 6x8, or 7x9 ins. in size, placed far enough apart to let in the Lorenz spring, if one is used on the head rod, and framed together at the ends.

64. Switch Ties.—Switch ties vary in length from 8½ ft. next the headblock of stub switches or at the heel of point switches, up to 14 ft. under the frog. Except for appearance, though, the first five or six ties under the lead rails next the headblock in a stub switch, may just as well be the common 8-ft. ties. It adds much to the appearance of things to have all the ends on the turnout side cut off the same distance from the lead rail of the turnout, or at any rate to have the lengths vary uniformly between the headblock and the last long tie under or beyond the frog. Where this is not done it is usual to base the order on 36 ties, in sets of three each, varying in length by 6 ins., from 8½ ft. up to 14 ft. and if more or less are needed one tie is added to or taken from each of so many of the sets of three. For a No. 9 frog 39 6x8-in. ties, or 38 7x9-in. ties, spaced 12 ins. apart in the clear, in either case, would be needed, the extra three being accounted for by including an extra tie in that many of the sets. Extra sets of 14½-ft. and 15-ft. ties (and in some instances 15½-ft. and 16-ft. ties) should be included and be placed beyond the frog, to avoid running the short ties of the side-track in between the ends of main-track ties where the two tracks separate. The number of ties required in any case is readily ascertained by dividing the whole distance by the sum of the space in the clear and the width of one tie face.

Ties for ordinary three-throw switch turnouts vary from 9 ft. next the headblock, up to 20 ft. at the heels of the two main frogs. The length of any tie may be found by doubling the length of the corresponding tie in a single turnout and subtracting the length of the standard track tie. The same number is required as for a two-throw switch. In laying switch ties for three-throw switches the middle of the tie should be placed on the center line of the middle track. This is readily done by marking the middle of the tie and using the track gage to get center. In three-throw switches where the main frogs are not placed opposite each other the length of any switch tie may be found by adding the two tie lengths corresponding to that position in both turnouts and subtracting from such sum the length of the standard track tie. The middle of the tie will then not come at the center of the middle track, but on that side of the center which is toward the shorter turnout, a distance equal to half the difference between the lengths of ties corresponding to its position in the two turnouts.

In two-throw switches it is not always advisable to put in long switch ties. If the turnout is laid for only temporary use it is a waste of labor and material to take out short ties, put in long ones, and then again to replace the long ones with short ties when the turnout is torn up. Short ties answer just as well for *ties* in turnouts as long ones do, the difference being that in case the track between headblock and frog gets out of surface long ties can be much easier and better tamped than short ones;

because the short ties in main and turnout leads must be so interlaid that there is little room left between them for tamping, except to work lengthwise under their ends. For six or eight ties next the headblock the main-track ties answer for the rails of both tracks, so that when short ties are used instead of long ones no ties for the turnout should be placed between the main-track ties as far as the turnout rails can be properly spiked to the main-track ties. The outside rail of the turnout curve should in any case be spiked to an occasional main-track tie, to prevent the turnout rails being crowded out of line in case of derailment. Whichever kind of tie is used (long or short) the spacing under the frog should be such that the toe and heel are made supported joints and a tie is placed directly under the point of frog, or as nearly thereto as may be allowable, with clamp frogs. Under point switches the ties must be spaced with reference to the tie rods.



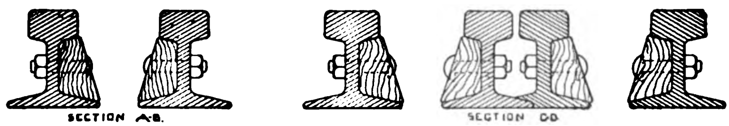


Fig. 137.—The Hart Foot Guard.

Where long switch ties are used in turnouts from the outside of curves, the elevation of the main-track curve comes the wrong way for the turnout curve. While this does not matter for the speed ordinarily made through turnouts, it makes a bad sort of arrangement in the turnout track where it leaves the switch ties, beyond the frog; for at this point the inside rail of the turnout curve is necessarily quite high. By using short ties instead of long ones a much better arrangement for the turnout curve can be made throughout, as it can then be made level across, opposite the frog, or the inside rail of the turnout curve may then be made lower than the outside one, without regard to the elevation in the main track.

65. Foot Guards.—Between two rails lying less than about 6 ins. apart in the clear, at the heads, there is a bootjack space from which one's foot, if caught, cannot be quickly released. Many trainmen have been trapped in such places while coupling cars and have been killed or injured. The laws of many of the states now require some form of guard to prevent feet from being caught in this way. The wings, mouth, and heel of frogs; guard rails, the lead rails at the toe of stub switches or the heel of point switches; or wherever the heads of two rails are more than 2 ins. and less than 6 ins. apart—should be blocked in such a manner that a foot cannot get caught between the lower corners of the rail heads.

Pieces of plank cut wedge-shaped to fit the space to be filled do very well. Such blocking after being driven snugly to place is made fast either by spiking to the ties or by drilling a hole through the webs of the rails and bolting it fast. The latter method is the better one, because it permits of removing the block without splitting it. The work of surfacing and other repairs occasionally requires the temporary removal of the guards. A wooden wedge guard for a plate frog must either be secured in this way or else be made long enough to reach a tie to which it may be spiked. The block for a guard rail should extend some 8 or 12 ins. beyond the end of the guard rail, so that it may be sloped down. Figure 137 illustrates a method of blocking the openings in frogs, guard rails and other places with wood, known as the Hart foot guard. The blocks of wood may be bolted to the web of the rail as shown or they may be secured by 60d wire nails driven through ¼-in. holes in the web of the rail and clinched on the block. The objectionable lower corners of the rail head are rendered harmless and dirt or other material falling on the frog has more room in which to be crowded out of the way of wheel flanges than is the case where the guard fills the whole space to the under sides of the rail heads. On roads where wooden guards are used it is quite customary to saw out the pieces to shape in the car shops from waste pieces of lumber and thus send them to the section foremen ready made. Where such is the practice the guards are cut to a few standard patterns and come very cheap. Cinder filling is also used for foot guards. It answers the purpose well enough, but snow and ice are not readily cleaned from it in winter, and in case it becomes necessary to remove the guard it is something of a job to pick out the frozen cinders.

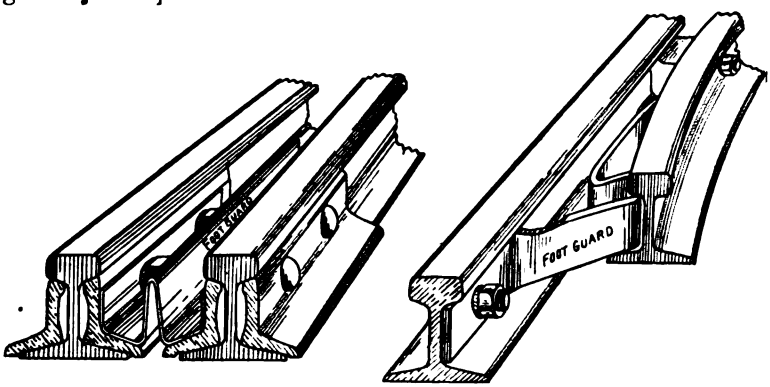


Fig. 138.—Looped Metal Foot Guard.

Of metallic foot guards there are several kinds, a common feature consisting essentially in adjustable wedges, spread apart either with or without springs. The Green guard (*A*, Fig. 120) has two flat plates, one above the other, held apart between the flange and head of the rails by spiral springs. The National guard consists of a telescoping box open on the under side, the two halves being spread apart by spiral springs. The Sheffield guard (Fig. 134) is a fan-tail device consisting of pressed steel plates ⅛ in. thick spiked to the ties. For guard and frog wing rails and lead rails the foot guard is of suitable length and in one piece, but for heel and mouth guards for frogs the device consists of two parts adjustable to the different angles of frogs ordinarily in use. No spring is used with this guard. In cases where the end of the guard does not reach a tie a hook extension with a hole for spiking is used. Figure 138 shows two forms of looped metal guard, that at the right, consisting of an iron strap or bar standing edgewise and looped back and forth between the rails, being known as the Nevens foot guard. The lead rail guard of this type consists of a bar presented edgewise and looped similarly at the wider end, but running straight for the greater portion of its length along the middle of the opening between the rails. The Weir foot guard is quite similar, consisting of a steel bar presented edgewise to the foot and held in position by brackets secured to the webs of the rails. Reference has already been made to a permanent solid guard for frogs made by extending the channel and mouth filling into the flare, as shown in Fig. 72. On some old-style rigid frogs in service on the Chicago & Northwestern Ry. the wing rails are not flared but are cut off short, and against the stub ends of the same a grooved cast piece is bolted to the frog, being shaped to form the filling of the channel and the flaring part of the wing, and therefore to serve as the foot guard. If the hight of the rail will permit it, the blocking of the heels of frogs, split switches, and derails can be much facilitated by entering the bolts of the splice bars so that the nuts come on the gage side of the rail; moreover, the nuts can then be more easily got at when loose. The laws of Canada permit railway companies to remove foot guards from frogs and guard rails during the winter months, subject to the approval of the railway committee of the privy council. The idea is that the removal of the guards facilitates clearing the parts of snow and ice, but all of the railways of Canada do not avail themselves of the privilege.

66. Switch Lamps.—Wherever night trains are run there should be lights to indicate the position of the switches. On single track, or where there are stub switches or facing-point switches on double track, it is foolhardy to run trains at night without switch lights; nevertheless, on some roads this is done. The usual arrangement for holding the lamp in position is to shape the top of the target staff to fit a socket in the bottom of the lamp. To insure that the lamp will be put on with the lenses facing in the right direction the aperture of this socket should be of oblong section, or of such shape that the lamp cannot be put on to face toward the wrong quarter. A lamp having a heavy bottom or socket which fits down over the tip of the staff is a more stable affair than one which sets in a fork attachment held to the staff by a set screw. The jarring of the stand is liable sooner or later to work such a contrivance loose, and it is easily bent. In the case of either of these conditions the lamp is tipped from the upright position and the glow of the lens strikes the ground within a comparatively short distance of the stand or is sent skyward, thus misdirecting the intensity of the light. It is a good scheme to fit a spiral spring or block of rubber into the lamp socket, for in putting a lamp in position the wick may be jarred down if the lamp is dropped suddenly to place. Lights are most liable to be jarred out over stub switches, and unless the lamps for such places are provided with spring sockets or with spring-supported oil pots it is sometimes difficult to keep the lights burning. In any case it is necessary to look carefully to the surfacing of the headblock and watch the joint opening on the headshoes. At low or wide joints on the headblocks of stub switches the oil pots of the switch lamps have been known to turn somersaults or flop bottom up, and rigidly supported lamps have been thrown off the stand.

Color.—In the largest practice the colors for switch lights correspond with the colors of the switch stand targets; that is, a closed switch is indicated by a white light and an open switch by a red light. In order to give a distinct indication for switches not on main line some roads use white and green for switches from side-tracks and in yards. Where such switches are used at night only occasionally it is the practice of some roads not to light them at all, and, as a rule, such is undoubtedly the best practice to follow. On a goodly number of roads green and red are the colors for switch lights, and the practice is growing in favor. Notwithstanding that green is the standard color for caution it is nevertheless preferable to white for the safety indication of switch lamps, since it is not so liable to be mistaken for some lantern, house light or other white light. Another objection to the use of white is the possible breaking or falling out of a red lens, in which event, the light, if not extinguished, would show white and thus give a wrong indication. A green light is not visible as far as a white light but it can be seen far enough for all the purposes of a switch light.

On single track it is necessary to have switch lights show both ways; consequently two white or green and two red lights should show from each lamp. But on double track it is well to dispense with the back safety light, so that the lamp shows safety only on the side facing approaching trains on its track. There is no necessity for showing a safety light to trains which do not use the track on which the switch is located. Unnecessary lights tend to confusion, where many are near together; and when seen at a distance, around a curve, there is no visible evidence to an engineer as to which of the lamps are showing for his track. By retaining the two red lights there will be positive evidence of danger when, as sometimes happens on double track, trains running both ways must temporarily use the same track. Some, however, prefer the use of only one red light, so as to avoid showing danger to an approaching train on the opposite track when the switch is set for the side-track. It is evident that where one or more of the lenses in a switch lamp is dispensed with the lamp should fit the socket in only one way out of the possible four—that is, the same lens should always face the same quarter for the same position of the switch. To insure that no mistake will be made in placing the lamp one corner of the tip of the switch stand shaft may be chamfered and the corresponding corner of the socket filled, or one side of the tip may be grooved for a rib in a corresponding position in the socket.

Lamp Construction and Design.—Switch lamps are made of tin, sheet iron, galvanized iron, sheet steel or cast iron. Heavy galvanized iron or sheet steel is more durable than tin, as it is not so easily warped when heated or so easily jammed out of shape in handling. The lamp should be put together with rivets in preference to solder, as then if the oil pot explodes and burns out, the lamp will not fall apart from the melting of the solder. The Monitor switch lamp has a cast iron body, in one piece, without solder or rivets. In general, switch lamps are composed of three principal parts; namely, a case for holding the lenses, a base, to which the socket is usually attached, and an oil pot and burner. Quite frequently the case and base are one piece or are permanently joined together, the oil pot being removed through an opening in the top which has a hinged cover, or through a hinged or vertically sliding door in the side. Where the case and base are separable the attachment is usually by means of a bayonet catch lock (Engraving *E*, Fig. 139). In some lamps, however, there is no base proper, the case being supported upon a fork attachment to the switch stand which fits into tubes at the side (Engravings *S*, Fig. 139), the oil pot then being inserted into the bottom of the case and held in position by means of a spring snap (Engravings *P* and *S'*, Fig. 139). If the top is hinged or removable the opening should be large enough to admit one's hand, because the surest way to light a switch lamp in a hard wind is through the top.

Figure 139 shows several designs of switch lamps. Engravings *H* and *G* show two patterns of Gray switch lamps, the latter being used on the Boston & Maine, Central Vermont, New York, New Haven & Hartford and other roads. On this lamp the lower part of each lens guard is omitted, the object being to remove any support on which snow might lodge and partially obstruct the light. The lenses in lamp *H* are not guarded. En-

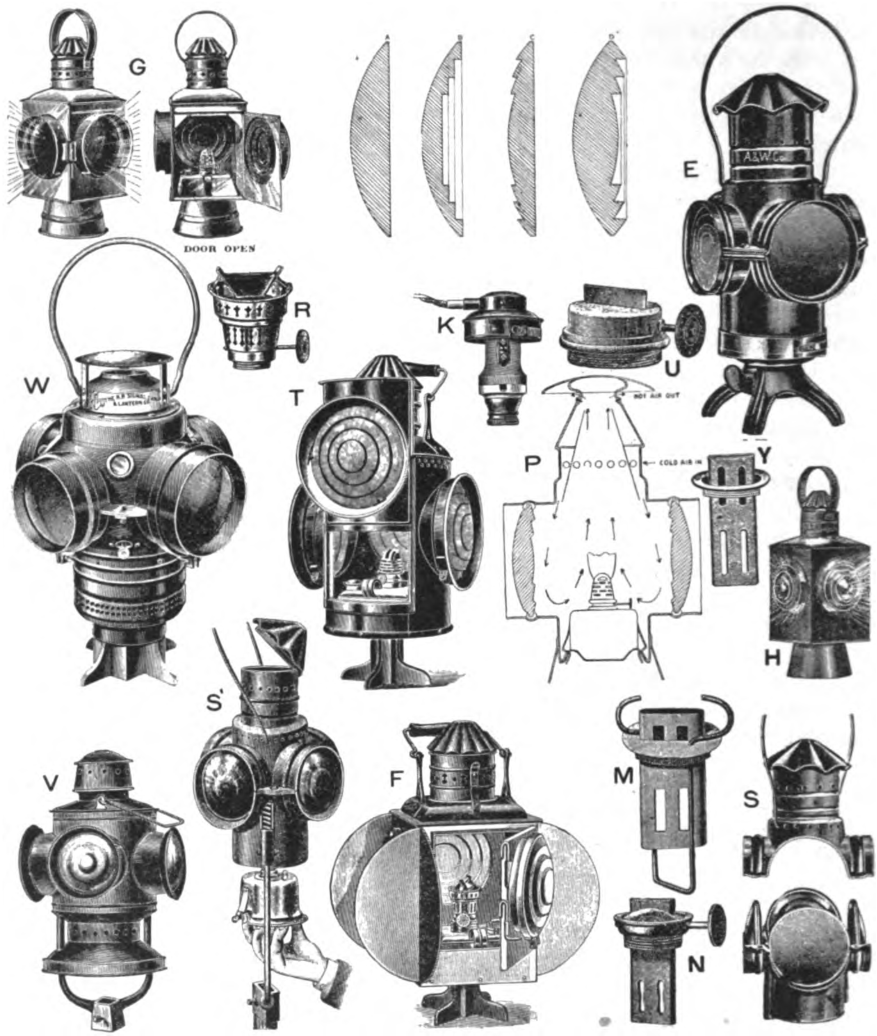


Fig. 139.—Switch Lamps.

gravings *E, S* and *S'* show two designs of the Bessemer heavy sheet steel lamp, the first being provided with a malleable iron base with socket, and the second and last with a fork socket or fork tubes with spiral springs in the tops of the tubes (*S'*) to relieve the jar. Both of these lamps are ventilated at the top by the Watt "upper draft, non-sweating" system, shown by diagram in Engraving *P*. The manner of placing the lenses is shown by Engraving *S*, and the manner of removing the oil pot by Engraving *S'*. Engraving *W* shows the Armspear switch lamp, provided with a spring socket, to relieve the lamp from the jar of passing trains, and with a hinged top. The spindle for adjusting the wick extends through the case, so that it may be turned from the outside, and there is a glass covered peep hole for observing the hight of the flame. In this lamp the safety and danger lenses are of different size, thus rendering it impossible to make a mistake when replacing broken lenses. Engraving *V* shows an Adams & Westlake switch lamp with spring-seated fork tube socket, the oil pot being removed from the bottom of the lamp. On low or dwarf stands where the lamps are attached in this way it is quite customary to reverse the fork on the top of the shaft, turning it up side down, and leaving it in that position during daytime, so as to get the prongs out of the way.

Engraving *T* shows one pattern of Dressel switch lamp, with sliding side door. Engraving *F* shows the standard switch lamp of the Pennsylvania R. R., including the Philadelphia, Wilmington & Baltimore R. R. It is a combined lamp and target, and is used on all facing-point switches and all switches within yard limits, whether facing or trailing. On trailing switches outside of yard limits no switch lamps are used, as stated in connection with switch stands. On some divisions of the road the practice of dispensing with lights and targets on trailing switches at outlying points is not standard, as the advisability of so doing is left to the discretion of the division officers. The targets are of steel, riveted to the square lamp case and painted to correspond with the color of the lenses. This lamp is placed upon a low spindle 4 ft. outside the rail, opposite the second switch rod, to which the spindle crank is attached by a connecting rod passing under the stock rail. The lamp remains in place during daytime, being permanently fixed to the spindle, and is filled, cleaned, lit and painted on the ground. On the Denver & Rio Grande R. R. there is in extensive service a switch stand designed with a large cast iron bulb in a break in the crank shaft about half way between the hinge of the lever and the target. In four sides of this bulb are placed the lenses, and inside it are the font and burner for the switch light.

Lenses.—The ordinary size of lens for main-line switch lamps is 4½ to 5⅜ ins. diam. For yard switch lamps 4 ins. in diam. is a common size of lens for intermediate switch stands and 3 ins. is the ordinary size for dwarf stands. The blue lenses for back lights in dwarf stands are usually 2 ins. in diam. Bridge lamps and pot lamps for tunnels have lenses as large as 8 or 8⅜ ins. diam. Lenses for switch lamps should be plano-convex or double convex rather than flat panes, as the two former concentrate the rays into a parallel beam and throw it stronger and farther. Generally, concentric portions of such lenses are taken out to lessen the weight. The absence of these portions from either face does not affect the efficiency of the lens, for when taken from the convex face the convexity is not changed, being simply telescoped. But if taken from the outer face the creases will catch dust and sleet or snow, impairing the efficiency of the light at times. It is better therefore to have the broken or "corrugated" surface inside the lamp, even though such adds some difficulty to the cleaning of it. Figure 139 shows three forms of plano-convex lens, *A, B* and *C,* the first being known as a "solid" lens and the other two as "corrugated" lenses. Engravings *D* and *P* show double convex lenses. The lens, of whatever color, should be one solid piece. Colored lenses are sometimes built up like the classification lamps of engines, by sliding a thin pane of colored glass behind a white bull's-eye. Such is a dangerous arrangement for switch lamps, for if the flame of the lamp becomes too high the thin colored glass may break from the heat and drop out of place, allowing the lamp to show a white light and thus give a wrong indication. It is important to have the flame of the lamp at the focal point of the lens; otherwise the light will not show so strongly. The focal length of each lens is usually marked on the glass.

Oil and Burners.—Kerosene is better than lard oil for switch lamps, because the former will burn all night without a readjustment of the wick, whereas lard oil not always will, particularly if of poor quality. It is seldom that lard oil, one time with another, runs uniformly. If there is too much mineral oil in the mixture it will smoke, heat up the oil pot and explode or throw out the burner; and if there is not enough of it the oil will thicken or freeze in cold weather. On some roads where lard oil is used it is the practice to increase the mineral ingredient in winter time. The Minot heater for lard oil burners (Engr. *M*, Fig. 139) consists of a wire looped to reach down into the font, with the tip ends bent around to touch or nearly touch the flame. The heat conducted along this wire warms the oil and prevents it from thickening. The ordinary plain flat burner for lard oil lamps is shown as Engr. *Y*. Style *N* is the same burner with a ratchet for adjusting the wick and Style *U* is the Dudley burner. The burners for switch lamps using kerosene oil are usually made with a flame spreader (Engr. *R*) which dispenses with the use of a chimney. The spindle for raising the wick should extend to the outside of the lamp, so as to enable the light to be adjusted out of doors in windy weather without opening the lamp.

To save cost of attendance a long-time burner, known as the Dodson switch and signal lamp, is used on a number of roads, among which are the Norfolk & Western, the Delaware & Hudson and the Atchison, Topeka & Santa Fe. The features of the lamp are a large oil pot, a small flame and reflectors to concentrate the light. The oil pot or reservoir holds about a quart and the wick is round and about ½ in. in diam., burning a flame about ¾ in. high. There is a short tubular chimney, and below and above the flame there are reflectors (the chimney extending through the upper one) shaped to throw the light into the lenses. The so-called lamp consists of the oil pot and burner with its reflectors and globe, and is made to fit any switch lamp. In actual service, with a good quality of oil, it burns continuously about seven days without refilling, trimming or attention of any kind. If the oil is poor the wick will crust over and require attention more frequently. The volume of light from this lamp is not as great as it is from ordinary switch lamps.

Electric Switch Lights.—In yards where there is a large number of switches, it is a convenience and a saving of a great deal of labor to light the signal lamps by electricity. If there is an electric light plant, an electric light circuit or a night-operated power plant in the vicinity the extra expense for the switch light service is not usually excessive, and the wiring of the necessary circuits is a simple matter. Incandescent lights of 8 candle power and 4 candle power are the ones most frequently used. Matters of particular convenience are that the lamps, which do not require cleaning, do not have to be taken down during the daytime, and remain permanently upon the switch stands; and the duty of lighting up or extinguishing the lamps on all the switches may be performed just at the proper time, by simply throwing a circuit switch in the power house. In lighting up the switches of a large yard with oil lamps it is necessary to begin placing the lamps an hour or two before they are needed, and, likewise, in taking them down in the morning, part of the lamps burn a considerable time in daylight. Engraving *K*, Fig. 139, shows the Dressel electric attachment for switch lamps, being an incandescent lamp socket suspended from a cap fitting over the top of the lamp case.

In order to show something of practice in the arrangement of electric lights in switch lamps and the connections therefor, the details of two or three installations of the kind will be described. In the yards of the Atchison, Topeka & Santa Fe Ry., at Ft. Madison, Ia., the switch lamps are of the ordinary pattern, with an incandescent electric light of 8-candle power, fitting a socket inside. As first installed, the wiring was brought to the switch stand in an underground pipe line, which was tapped by a branch pipe standing vertically 3 or 4 ft. clear of the stand and arching over so as to enter the top of the switch lamp. Some trouble was experienced with this method of bringing the circuit to the lamp, as the switchmen, in throwing the switch, took hold of the pipe with one hand and the lever of the switch stand with the other, with the result that the pipes were frequently pulled over and the circuit broken, the lamp socket short-circuited, or the filaments of the lamp broken by the jar. Accordingly, this method of leading the circuit to the lamp was changed and by the new plan the circuit was run up the switch stand so as to enter the lamp casing from below.

In the yards of the Ogden Union Railway & Depot Co., which serve for the terminals of the Union Pacific, the Southern Pacific and the Oregon Short Line roads in Ogden, Utah, the switch signals are lighted by 16-c. p. incandescent lamps on a 110-volt circuit from a plant owned by the terminal company for lighting the depot buildings, freight houses, transfer sheds and the grounds. The top part or casing of an ordinary oil switch lamp is used, on a fork attachment, as shown in Fig. 139A, and the wires, which are brought in under the hinged ventilation cap, are suspended from a pole set 5 to 7 ft. from the switch stand. These poles, which do not appear in the view, are high enough to carry the wires, where they cross the tracks, well above the cars. The lamp socket is rigidly attached to a cup made to fit the inside of the top part of the lamp case.

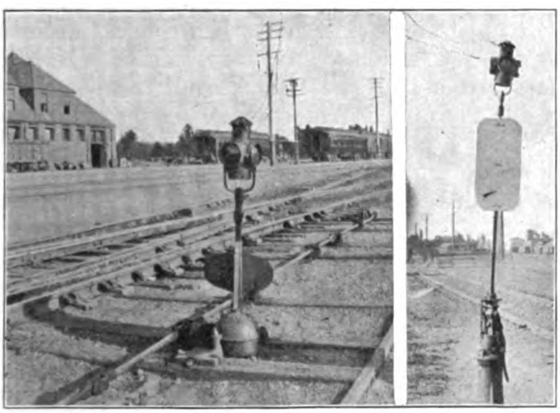


Fig. 139 A.—Electric Switch Lights, Ogden Union Ry. & Depot Co.

In the Chicago Clearing Yard (Fig. 214A), operated by the Chicago Union Transfer Ry., the lamps on something like 425 switches are lighted by 8-c. p. incandescent electric lights. These lights are arranged on four circuits running separately from the power house. The electric current on the circuits as they leave the power house is at high potential, and transformers are distributed at points along the yard, from which secondary circuits radiate to the switch stands. These secondary circuits consist of lead covered cables laid in iron conduits, making a water-proof arrangement. The switch lamps have special castings for the electric attachments, so as to facilitate the removal of the electric bulbs and make them easily accessible for inspection or repairs. At the power house there are special instruments installed, one for each circuit, showing at any time the actual number of lamps burning on the circuit, thus giving a constant check at the power house to show whether or not any individual lamp has burned out in service. The importance of this arrangement may be appreciated when it is considered that much time would be required to go over the entire lot of 425 lamps to find whether or not all were burning.

In connection with the Taylor system of interlocking, electric lights of one-candle power are being used in the switch lamps. Such were adopted after a sufficient number of trials to demonstrate that an electric light of this power, placed at the focus of the lenses, is satisfactory. Four of the lights are arranged in series on a 110-volt circuit. The current used is $\frac{1}{5}$ ampere.

Care of Switch Lamps.—All dirt, oil and soot should be wiped from the lenses and other portions of the lamp daily, and the font should be emptied and rinsed as often as the oil in it becomes greenish or dirty. The wick should be trimmed by scraping off the burnt portion with the fingers or with a match stick, and not by cutting. While the lamp is not lighted the wick should be turned down so that its top is within the tube, to prevent overflowing of oil. The wick should be long enough to reach the bottom of the font and the latter should not be filled higher than a half inch below the top. The air vents of the burners should be kept open, and when the wick becomes clogged with refuse matter a new wick should be substituted. Trouble from clogging of the wicks is usually caused by dirty oil or oil of poor quality, the impurities in which are separated by the seepage process in the wick. After lighting a lamp it should be allowed to burn for a time and heat up the burner before the wick is finally adjusted. As the burner warms up the flame naturally increases in size, and the lamp should not be left until the wick is properly adjusted; otherwise the lamp may smoke, after a few minutes. In foggy weather it is customary to light switch lamps earlier than usual and permit them to burn later before taking down in the morning. Where switch lamps are numerous within carrying distance it is a good plan to take them all to some central point for cleaning, filling and lighting before they are distributed in the evening. Light hand cars (described in § 133, Chap. IX) are much used for carrying switch lamps.

A convenient arrangement for carrying switch lamps by hand is to hang them on a pole and carry a pole-load in each hand. In order to load the poles to a balance at the middle, notches may be cut or nails driven into the top side of the pole to indicate regular spacing intervals. By means of a stout leather strap buckled to the poles and passed over one's shoulders a heavy load of lamps may be easily carried. If, however, the switches are widely scattered it is a waste of time to carry the lamps back and forth, and the best plan is to have a box under lock at each isolated switch and at each point where a few switches are grouped within convenient distance, to which the lamps may be taken to be cleaned and filled and sheltered during the daytime. If lard oil is used which tends to thicken in cold weather it will save trouble to carry a can of warm oil from box to box and fill the lamps just before lighting them, in the evening. The most trouble in this respect usually comes from the practice of filling the lamps in the morning, so that the oil remains in the cold lamps all day. If the oil is of fair quality and thin when the lamp is lighted the heat of the burner will usually prevent it from thickening. In putting up or taking down switch lamps the track-walker or lamp tender should keep his greasy hands off the targets. To enable lamp tenders to clean lamps properly and keep them in neat condition they should be supplied with clean new waste.

The Michigan Central and the Atchison, Topeka & Santa Fe roads have complete sets of rules governing the care of switch and other signal lamps. On the A., T. & S. F. road there is a standard lamp body for all signal purposes, and all signal lamps, including semaphore, switch, order board, train marker and engine classification lamps, are in charge of the signal department. To see that the signal lamps are properly cared for there is a lamp inspector reporting directly to the signal engineer and also to the various superintendents, trainmasters and roadmasters. His duties are to travel over the road continually, visit all points where signal lamps of any description are used, inspect them carefully and report their condition to the official in direct authority over the man caring for the lamps. He also instructs persons in charge of lamps as to their proper care and is supposed to see that the rules are obeyed.

All new lamps on the line are issued from Topeka, and at that point also all the damaged and defective lamps are repaired. Once a month the lamp inspector returns to Topeka to inspect and test all new and repaired lamps and to mark with a special stamp all those which pass inspection. The storekeeper is not permitted to issue lamps which do not bear the stamp of the inspector. Adjacent to the shop where all the lamps are repaired there is a suitable testing room equipped for the use of the lamp inspector. Close to the repair shop are two vats, one filled with lye and one with hot water, and near-by is a room provided with a number of hooks at one end and a small bin at the other. All lamps and burners that come in off the road are placed in one end of this room, the burners being put into the bin. Once a month the lamp inspector visits this room and carefully inspects all the lamps and burners, throwing out the worthless ones for scrap and laying to one side all that are worth repairing. These are then dipped in hot lye and afterwards in hot water, which removes the paint, oil, soot and dirt from the lenses and lamp. They are then dried and sent to the tinsmith, who makes the necessary repairs, gives them a serial number and letter, if they do not already have one, and then sends them to another room where they are painted and hung up to dry. When dry they are carried to the inspector's testing room, where they are subjected to the blower test for leaks, are examined to see if the lenses are in right, and are tried on the particular switch fork, bracket, or holder, to which they belong. If they are in proper condition the inspector marks them with a label, takes a record of the number and sends them to the storehouse to be issued on requisition.

In addition to the foregoing the lamp inspector is required to submit all new lamps and lenses used on any line of the system to the following tests: Blower test, under pressure measured on a Pitot tube the equivalent of a wind velocity of 80 miles per hour; and the color test. All lenses must be free from waves, air bubbles, or imperfections on the outer or inner convex surfaces. Ruby and green lenses and colored semaphore glass must be of the same color and depth of color, within the limits established as maximum and minimum standard colors. All color tests must be made with standard burners, with flame 1 in. high properly focussed on the photometer bar in the lamp inspector's office. There are, on an average, 250 lamps repaired and inspected each month, the repairs being made by one tinsmith and helper, including everything excepting the painting, which takes from six to ten hours a month for one man. The list of rules relating to the care of signal lamps on this road is given in §199, Supplementary Notes.

The rules of the Michigan Central R. R. are similar to those of the A.,

T. & S. F. Ry.; in fact the latter were largely copied from the former. The following is a blank form for a defective lamp report:

MICHIGAN CENTRAL RAILROAD.

DEFECTIVE LAMP REPORT.

____________ Station ____________ 190 __

To ____________

At ____________

Type of Lamp ____________

Trouble with Lamp ____________

If damaged externally, by what means ____________

NOTE.—A blank must be filled out and placed inside of each lamp sent in.

Signature ____________

Occupation ____________

This blank is printed on a stiff card $3\frac{1}{4}$x$5\frac{1}{4}$ ins., and, as required by the instructions, is filled out and placed inside of each lamp sent in to headquarters for repairs.

67. Clearance Posts.—Some mark or reference object ought always to be at hand to indicate the shortest distance beyond the frog at which a car standing on the side-track may be safely passed by trains on main track. Unless the track be heavily elevated toward the inside (a very unusual condition) 12 ft. between track centers will give ample room for passing. This distance between centers gives about 7 ft. between the outsides of the two near rails; some make it $6\frac{1}{2}$ ft. On the Chicago, Burlington & Quincy Ry. the standard clearance distance is 7 ft. for main tracks and 6 ft. $3\frac{1}{2}$ ins. for side-tracks. A post about 4x4x36 ins., standing about 8 ins. out of the ground, is sometimes set midway between the two tracks at the clearing point. The post is usually painted white with a black tip, the top corners being rounded off. In this position the post is a source of danger to trainmen running between the tracks after dark and for this reason they are often pulled up and thrown away. A better location for the post is outside of either main or side-track, opposite the clearing point, 4 or 5 ft. from the rail, and on the Canadian Pacific Ry. this principle is followed, the post being placed outside the turnout track. The sign is conspicuous, being a black board with two white disks, nailed to a tall post. The standard clearance post on the main line of the Southern Ry. is cast iron, of +-shaped section, flattening out into a plate at the top, painted white and lettered "C. P." in black. On some of the branch lines a wooden post, painted white and lettered "Clear this Post," is used. In each case the post is set between the tracks. On railways in India the standard reference for clearance is a whitewashed half-rounded tie laid across the space between the tracks.

68. Point Switches.—In computing the lead distance and radius of point-switch turnouts it has been quite commonly the practice to use the formula for stub switches. Without looking into the matter it is naturally enough supposable that the lead from headblock to frog in a stub-switch turnout will answer for the lead from heel of point rail to frog in a point-switch turnout, the throw in the one case being about the same distance as the spread in the other; and in practice this is what has actually been done to quite a large extent. While these lead distances from the two kinds of switch are nearly the same for frogs up to and including No. 9, still the problems are essentially different in the two cases, and within this range of frog numbers the turnout curvature for the point switch is considerably the sharper. In comparing the two types of switch it should be borne in mind that the stub switch rails when thrown for the siding form part of the turnout curve, while the point-switch rails do not, and this is why there is no close agreement of turnout curvature for the same frog in the two cases. With frogs of higher number than 9 the lead distances corresponding to the two kinds of switch and the same frog differ too widely to be overlooked, the stub-switch lead being too long for the point-switch turnout. The term "shortened lead," so largely in use among trackmen, refers to a point or split switch with a stub-switch lead—that is, a lead calculated for a stub switch, with the heel of the split rail spliced on at the point corresponding to the position of the headblock of the stub switch. As the point switch of ordinary length (15 to 18 ft.) is shorter than the stub-switch rail for all frogs of higher number than $6\frac{1}{2}$, a point switch used with a stub lead falls short of the point corresponding to the heel of the stub switch (point of curve), and hence it is commonly supposed that the "theoretical" lead is "shortened." In a strict sense the term is a misnomer, for the stub lead is not the "theoretical" lead for a point-switch turnout.

With the point switch the turnout curve begins at the heel of the point rails. It meets here a straight switch rail at a tangent, and on the headblock the switch rail meets the main-track rail at an angle, the degree of which depends upon the length of the switch rail and the spread at its heel. In a comparatively few instances the switch rail is curved to the turnout, but such is not general practice, and nothing of account is gained by curving the point rail between the end of the planed portion and the heel. In Fig. 140 let $A\ L$ and $K\ F$ be the gage lines of two main-track rails, and let the gage be represented by g. Let F be the frog point and let the angle $D\ F\ K$ represent the frog angle, which we call F. Let $A\ B$ be a switch point rail, of length p, making an angle with $A\ L$ which we will call P. Let $B\ C$ be the spread at the heel B. and call it h. The conditions require that a circular curve be drawn through F tangent to the line $D\ F$ and meeting at the other end (B) a straight switch rail at a tangent when the switch rail is in the position of open switch. The formulas for the measurements necessary to lay out the switch appear below. For the derivation of the same the reader is referred to the Railway and Engineering Review of Apr. 2, 1898.

(1). Lead distance $K\ F = \dfrac{(g-h)(\cos F+\cos P)}{\sin F+\sin P}$

In words, the lead distance from heel of switch rail to frog point is the quotient of two quantities, the dividend being the gage of the track less the spread at the heel, multiplied by the sum of the cosines of the frog and switch point angles, and the divisor the sum of the sines of these two angles

(2). Radius of outer rail $B\ F = r+\frac{1}{2}g = $ also $\dfrac{g-h}{(\sin F+\sin P)\ \text{tang}\ \frac{1}{2}\ (F-P)}$

(3). Chord $B\ F = \sqrt{[(K\ F)^2+(g-h)^2]}$

(4). Middle ordinate $O\ N = (r+\frac{1}{2}g)\ \text{vers}\ \frac{1}{2}(F-P)$

Substituting the values of $\sin F+\sin P$ and $\cos F+\cos P$ in other terms these formulas are rendered calculable by logarithms and we have:—

(1′). Lead distance $KF = \dfrac{g-h}{\text{tang}\,\frac{1}{2}(F+P)}$

(2′). Radius of outer rail $= r + \frac{1}{2}g = \dfrac{g-h}{2\sin\frac{1}{2}(F+P)\sin\frac{1}{2}(F-P)}$

(3′). Chord $BF = \dfrac{g-h}{\sin\frac{1}{2}(F+P)}$

(4′). Middle ordinate $ON = (r+\frac{1}{2}g)\,\text{vers}\,\frac{1}{2}(F-P)$

$$= \text{also}\ \frac{(g-h)\,\text{tang}\,\frac{1}{4}(F-P)}{2\sin\frac{1}{2}(F+P)}$$

Tables XIII and XIV (see index for page number) give the lead distances and other measurements for point-switch turnouts corresponding to frogs of different numbers, various lengths of switch point, spread at the heel etc.

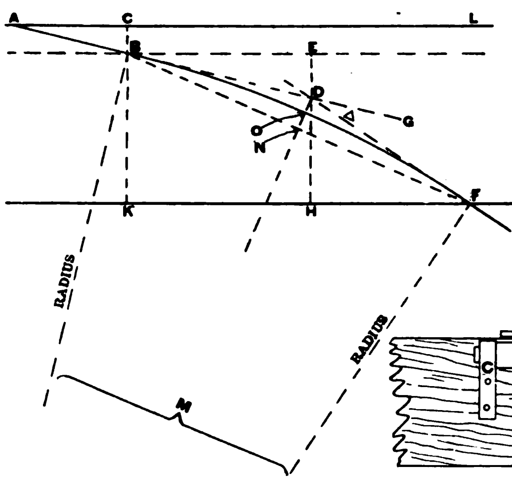


Fig. 140.

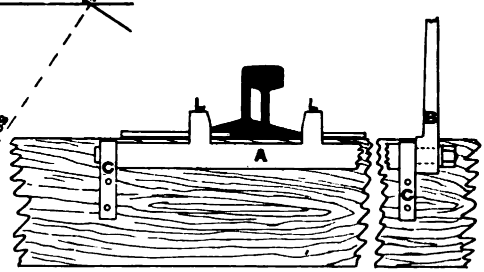


Fig. 141.—Switch Point Lock.

When the toe of frog or other point on the frog leg, instead of the point of frog, is made or assumed as the end of the lead curve, as is sometimes done, certain modifications of the above formulas, as applying to lead distance and radius of curvature, are necessary. In that case the value of g in the formula must be decreased by an amount found by multiplying the distance from frog toe or end of lead curve to frog point (call this distance k) by the sine of the frog angle F. The lead found by using this value of g must then be increased by $k \cos F$. We then have:

(1″) Lead distance $KF = \dfrac{(g-h-k\sin F)(\cos F+\cos P)}{\sin F+\sin P} + k\cos F$

$$= \text{also}\ \frac{g-h-k\sin F}{\text{tang}\,\frac{1}{2}(F+P)} + k\cos F$$

(2″). $r+\frac{1}{2}g = \dfrac{g-h-k\sin F}{(\sin F+\sin P)\,\text{tang}\frac{1}{2}(F-P)} = \text{also}\dfrac{g-h-k\sin F}{2\sin\frac{1}{2}(F+P)\sin\frac{1}{2}(F-P)}$

(3″). Chord (heel of switch rail to toe of frog) $= \dfrac{g-h-k\sin F}{\sin\frac{1}{2}(F+P)}$

(4″). Middle Ordinate $=(r+\frac{1}{2}g)$ vers $\frac{1}{2}(F-P)$

$$=\text{also } \frac{(g-h-k\sin F)\tan g\frac{1}{4}(F-P)}{2\sin\frac{1}{2}(F+P)}$$

Mr. Wellington B. Lee has developed a set of arithmetical formulas for finding the lead and radius in point-switch turnouts which are based upon the frog and switch-point numbers. These formulas, in connection with an article of some length, were published in the Engineering News of Apr. 21, 1898, and subsequently reprinted in the switch and frog catalogue of the Ramapo Iron Works, Hillburn, N. Y. The formulas are given below. Employing as far as possible the foregoing notation, the switch number (n) is the length of switch rail (p) divided by the spread at the heel (h), or $p\div h$. Let the frog number be represented by N, the gage by g, and the spread at the toe of the frog by f. We then have

(A). $d=g-h-f$

(B). Chord of outer rail in turnout, from heel of switch rail to toe of frog, $=a=2dnN\div(n+N)$

(C). Main lead, heel of switch rail to toe of frog, $=b=\sqrt{(a^2-d^2)}$

(D). Radius of outer rail of turnout $=r+\frac{1}{2}g=anN\div(n-N)$.

(E). Middle ordinate of chord $a=a^2\div 8(r+\frac{1}{2}g)$

In the case of a frog having the turnout leg curved between toe and point of frog the spread (f) at the toe becomes zero, for the purpose of the formulas, and the chord distance (a) and lead distance (b) then extend from heel of switch rail to point of frog.

The middle ordinate of the outside rail of the point-switch turnout does not remain constant for different frog angles, as it does with the stub-switch turnout, but decreases with decrease in the angle of the frog (although not in the same ratio) until that angle equals the angle of the switch point, when the middle ordinate becomes zero and the turnout curve becomes a straight line throughout, from point of switch to point of frog. And unlike the formulas for stub-switch turnouts, those for point or split-switch turnouts do not apply with a close degree of approximation when the main track is curved. The following modifications of the same are reliable, however, and give results which, within the range of the frog numbers in common use, are very close to the exact values and certainly near enough for track purposes. First, when the turnout is *with* the curve, the degree of turnout curve is increased very approximately by the degree of curve of main track; but the lead distance is longer than that for straight main track; and the change in middle or quarter ordinate of outside rail, per degree of curve of main track, is not found by dividing the ordinate for straight track by the degree of turnout curve for straight track, as in the case with the stub switch. The difference in lead may be found by dividing the square of the frog number by 144 and multiplying the quotient by the degree of curve of main track ($Dn^2\div 144$). Add this result to the lead distance for straight track. To find the change of middle or quarter ordinate per degree of curve of main track, divide the ordinate for straight track by the degree of turnout curve for straight track and multiply the quotient by $1\frac{1}{4}$; that is, (ord.$\div D)\times 1\frac{1}{4}$. Multiply this result by the degree of curve of main track and add the product so found to the ordinate for straight track.

When the turnout is *against* the curve, the degree of turnout curve is not decreased approximately by the degree of curve of main track, but at a faster rate. The proper lead distance is found by subtracting from the lead distance for straight track an amount equal to $Dn^2 \div 144$, where n is the frog number and D is the degree of curve of main track. The change in middle or quarter ordinate per degree of curve of main track is found by dividing the ordinate for straight track by the degree of turnout curve for straight track and multiplying the quotient by $1\frac{1}{8}$; that is, $(\text{ord.} \div D) \times 1\frac{1}{8}$. Multiply this change so found by the degree of curve of main track and subtract such product from the ordinate for straight track.

Finding Lead without Computation.—The lead distance of a point-switch turnout may be found quite readily and with sufficient accuracy by a little rough surveying on the ground, or by a scale drawing on paper. Referring to Fig. 140, it will be noticed that the condition essential to a circular turnout curve between frog and switch-point rail is that the two tangents BD and DF shall be of equal length. All that is necessary, then, to find the proper location of the switch, after establishing the location of the frog, is to ascertain by string measurements what position of the switch rail will bring these tangents equal. This work the trackman may go about in the following manner: First determine upon the location of the frog point (F) and then stretch out and stake down a string in the direction of the turnout gage line of the frog. This direction may be found by placing the frog on top of the rail in proper line or by setting a stake on a line which diverges from the main rail according to the spread of the frog legs. If the turnout leg of the frog is curved the proper spread may be given to the string by knowing the frog number; as, for instance, if a No. 9 frog is being used set a stake 2 ft. from main rail (FK) at a distance of 18 ft., or 3 ft. from that rail at a distance of 27 ft., from F. With the string stretched through the points D and F, fit the switch-point rail against the main rail and stretch out a string along the gage side straight beyond, shifting the point rail back and forth until the intersection point D is equally distant from B and F; or from B and the toe of the frog, in case the latter point is made the end of the turnout curve. This method applies to the problem of laying a turnout in either straight or curved track. In case the main track is curved the spread of the tangent line DF should be measured not from the main rail FK but from the gage line of the main rail of the frog produced.

Regarding the alignment of the turnout from toe to heel of frog some engineers set forth views and specifications more finely drawn than any necessities of the case would seem to require. The old idea was that there should be a piece of straight rail in advance of the frog to swing the car trucks into line with the same and thus avoid any centrifugal tendency in the wheels and side pressure against frog or guard rail. Accordingly, it was to some extent the practice in the early days to lay the turnout leg of the frog straight and continue the track straight for a few feet in advance of the toe of the frog. The advantage in this arrangement is more fancied than real, for the centrifugal force in the body of a car does not disappear until the whole car has passed out of the curve; and the piece of tangent in front of the frog appreciably sharpens the turnout curvature for the same frog angle. Moreover, the path traveled by a wheel over a frog is not fixed altogether by the alignment of the frog, but quite largely, if not entirely, by the guard rail opposite, so that, in any event, the wheel is not likely to take a straight course through the frog. With frogs of proper length it is feasible to spring the leg to the curvature of the turnout within 3 or 4 ft. of the point of frog, and when such is done it is not worth while to consider the straight piece separate from the curve, in the computations. And finally, it has already been pointed out that the turnout leg of spring-rail frogs may just as well as not be curved when the frog is made, and the construction of frogs in this manner is growing in practice.

The advantages in favor of the point switch are that it cannot run tight from expansion in hot weather nor is its serviceability or safety affected by contraction in cold weather; there is no joint at the headblock to be pounded out of surface; and cars cannot be derailed in trailing the switch when it is open. There is only one way in which cars can be derailed at a point switch, and that is when the switch (of ordinary design) is partly thrown and the car or train meets the switch facing. In this event the wheels on one side of the track take the main rail and the wheels on the other side follow the turnout rail, thus resulting in derailment. But such an occurrence cannot result from forgetfulness. It is also to be considered that the point switch breaks the continuity of the main rails on only one side of the track, and then not by a squarely-cut joint, whereas the stub switch breaks the continuity of the rails on both sides of the track. The point switch is therefore a safer switch than the stub switch and should be maintained at less expense. About the only respect in which the point switch is inferior to the stub switch is that during winter time more attention is required to keep the switch clear of snow and ice. With the stub switch snow cannot be confined so as to interfere with the movement of the switch rails to the same extent that it can with the point switch. The stub switch is still considerably used in main track, particularly on mountain roads, the generally accepted explanation for the practice being that the heavy snowfall of such regions obstructs the operation of point switches more frequently than the switches can be properly looked after. On this question a brief quotation from an article by Mr. Jerry Sullivan on "Weather Conditions as Affecting Track in the Rocky Mountains," published in the Railway and Engineering Review of Apr. 22, 1899, is to the point. Mr. Sullivan says, in part:

"I do not see why split switches are not more generally used in the mountains. I believe the average number of delays to trains per year would be less with split than with stub switches, because the number of warm days in summer is many times greater than the number of stormy days in winter, and as between a tight switch and one covered with snow the time consumed in getting into a siding is much less in the latter case, because the brakeman can step to the engine and get a scoop and broom or coal hammer and get the points clear in less than 5 minutes; while in hot weather I have known trainmen to spend 15 minutes hammering with a coal pick, or trying to butt the rails over with a piece of scrap iron. Again, the rails of a stub switch may appear to be all right when the section gang passes over in the morning and they will not come back to look after it during the day; whereas, if split switches are used the foreman will send a man to clean them out in case of snow In this case he knows to a certainty when the weather will interfere with the working of a split switch, but in the other case he does not know when the stub switch will get tight. A snow storm in the mountains is usually limited in area, and may interfere with 50 or 75 miles of track, but a hot day will tighten switches on 300 or 400 miles of track. . . . I think the snow is a bugaboo; and I believe that later on our roads will use point switches and spring frogs and find them superior in every way, even at high altitudes."

Point Switch Construction.—The point or split switch consists of a pair of movable rails planed to wedge points and set to work against two fixed rails. A plain switch of this type, of ordinary design, is shown as Fig. 142. The rails *A* and *B* are the main-track rails, the latter being a lead rail. Rails *C* and *D* are in the turnout lead and the rails *P* and *P'* are the *point rails* or *split rails,* usually planed back on the head a distance of 6 or 7 ft. The switch is shown in the closed position, or set for main track. Rail *A* is known as the *through rail* and rail *E* as the *stock rail.* The latter is on the frog side of the track and is bent to the switch angle or to fit the planing of the point rail; some trackmen call it the "knee rail." The bend at *E* is sharp or angular, being put in with a jim-crow, and is usually made 10 to 15 ins. ahead of the end of the point rail, thus allowing for some thickness in the end of the point rail and for creeping steel. The track at *E* should therefore be right for gage. In addition to bending the rail at *E* it is quite widely the practice to "crank" it or kink it at the bend, so as to "house" or shield the end of the point rail behind the kink. While this "cranking" of the stock rail, as the English call it, permits the point rail to extend into the recess behind the kink, close to the bend and at the same time lie in even alignment with the general gage line, it is nevertheless objectionable wherever creeping steel is bothersome. If the stock rail creeps frogward or the point rail creeps in the opposite direction the kink will spread the point, and if the stock rail creeps from the point rail the kink will then protrude beyond the alignment of the point rail.

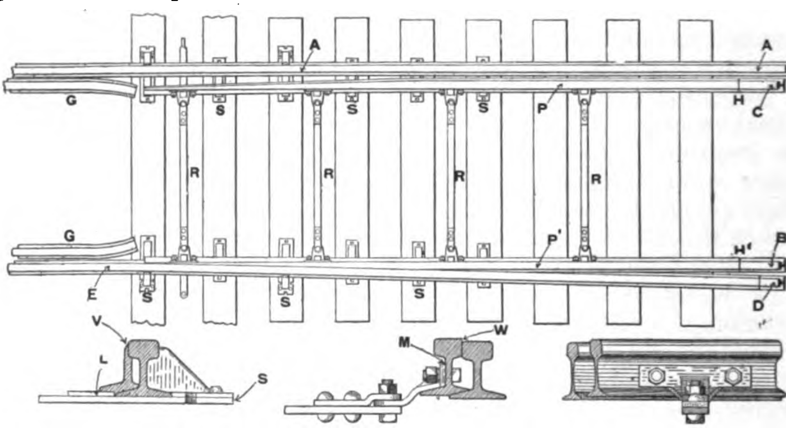


Fig. 142.—Point or Split Switch.

The most common length of switch point is 15 ft. This length is suitable, and the fact that a 30-ft. rail will make two 15-ft. points makes it a convenient length for the manufacturer. Point rails 18 ft. in length are quite common, however, and 20-ft. points are used with ordinary frogs to some extent. At end of double track 24-ft. and 30-ft. point rails are used in a few instances. In yards 10-ft. and 12-ft. point rails are sometimes used. The spread at the heel—that is, the distance between gage lines at the joints *H* and *H'*—is about the same as the throw at the toe of a stub switch, depending upon the width of the rail base. With rails of small section the spread may be 5 to 5½ ins., but with rails of 80-lb. section or larger the spread is usually 5½ to 6 ins. for 15-ft. points and 6 to 6½ ins. for 18-ft. points. A point rail 15 ft. long spreading 5½ ins. at the heel meets the main-track rail at the point of switch at an angle of 1 deg. 45 min.

The form of split switch now in general service is patterned after the Clarke-Jeffery design, which was worked out by Mr. Leverett H. Clarke, while chief engineer of the Illinois Central R. R., and Mr. E. T. Jeffery, then an employee of the same road and later president of the Denver & Rio Grande R. R. The distinctive features of this switch are: (1) The planing of the base of the point rail in a manner to seat it on the flange of the stock rail or main rail; and (2) the crowning of the point rail above the top of the stock rail (or main rail) at the point where the tread or tire of a wheel just reaches the gage side of the latter. The arrangement of seating the base of the point rail on the flange of the stock rail is shown in Fig. 142.

At the end of the point rail it is necessary to plane the head entirely away, both sides, down to the web, and in order to do this and have the gage side of the point rail straight the rail must be bent inward (toward the gage side), at the point where the planing of the head begins. From this point the gage side of the point rail head is then planed straight away to meet the web at the point end. To avoid heavy pressure from the wheels on the thin portion of the point rail the top of the same is planed down on a slope to bring the end ¼ in. or such matter lower than the top of the stock rail. This sloping of the top of the point rail is carried back 15 to 18 ins. from the end, and sometimes farther, as is presently explained. The idea in view is that the point rail should not extend as high as the stock rail until a point is reached where it is strong enough to bear the whole load. The effect of carrying the load on the point rail where it is too thin or too narrow is to crush the top surface, causing the metal to flow against the stock rail and spoil the adjustment. It is also customary practice to plane out the inside face of the point rail along the top edge (*V*, Fig 142), leaving a shoulder on the web to be housed under the head of the stock rail. This arrangement permits the full thickness of the web to be carried to the end of the point rail, thereby making possible much stronger construction than would otherwise be the case. In England a new method of making split switches is being tried, the points being rolled to a taper, out of ordinary rail, instead of planing the rail down. The idea in avoiding the use of the planing machine is to preserve the skin or original rolled surface of the rail intact, which is supposed to be tougher, and therefore better able to stand wear, than the planed surface of point rails made in the usual way. The taper-rolled rail is also supposed to be stronger than the planed one. Some of these rolled point switches are in use on the Midland Ry.

On each tie, at least as far back as the point where the bases of the point and stock rails separate, and sometimes a tie or two farther, the point and stock rails rest upon iron or steel plates (*S*) known as *slide plates.* These slide plates should extend under both point and stock rails, on the one side, and under both point rail and through rail on the other side. A short slide plate passing under the point rail only and abutting against the flange of the stock rail is not satisfactory under heavy traffic. Slide plates should also be of good width—at least 5 ins. They are frequently made so narrow that they settle into the timber when the ties become old, and in such cases one end of the plate usually dips and leaves the point and stock rails unevenly supported. As far as the point rail rests upon the flange of the stock rail or is higher than the stock rail the plates are stepped or thickened by a riser (*L*, Fig. 142) to make a proper bearing for each rail and hold the rails at the desired relative hight. This stepping of the slide plates is done either by shouldering a solid plate or by pressing up a portion of the same, or by riveting a shim to one end of a plain plate. The solid plate is preferable, as if the rivets in the built-up plates work loose they are liable to stick up and catch the point rail when the switch is thrown. As the risers decrease in thickness from the point toward the heel, or vary in thickness according to the position of the plate, it is important to lay the plates in their proper order, and to avoid mistake the plates should be stamped with numbers consecutively from the point toward the heel. Usually part of the plates (sometimes alternate ones) or all of them are extended outside the stock rail far enough to support a rail brace, which may be riveted to the plate or backed by turning up the end of the plate. An efficient brace may be made by splitting in halves that portion of the plate which extends outside the stock rail, punching a spike hole in one of these parts and then bending up the other half to hold the flange of the rail.

We now come to the second principle of the Clarke-Jeffery design. To prevent guttered tires or wheel treads from fouling the stock rail when trailing the switch, the point rail is cambered and raised $\frac{1}{4}$ or $\frac{3}{8}$ in. higher than the stock rail at the point where the overreaching tread meets the gage line of the latter; from this point it should slope down gradually both ways to the level of the stock rail. The difference in hight shown at *W* in Fig. 142 is not so necessary at that point as it is farther back where the rails are separated—say at the last tie bar *R*. Ordinarily the humping of the point rail to carry false flanges trailing the switch so that they will pass over the stock rail without spreading it is done in the following manner: The top or head of the point rail, in a length of about 5 ft. from the point end, is planed down on a gradual slope, striking $\frac{1}{2}$ to $\frac{3}{4}$ in. deep at the end. This planed top then slopes from a point $\frac{1}{4}$ to $\frac{3}{8}$ in. lower than the top of the stock rail to a point $\frac{1}{4}$ to $\frac{3}{8}$ in. higher than the top of the stock rail at the end of the 5 ft. For the next 5 ft. the top of the point rail runs level and $\frac{1}{4}$ to $\frac{3}{8}$ in. higher than the top of the stock rail, and in the next 3 to 5 ft. it drops, on risers of varying thickness, without planing, to the level of the stock rail. In this connection it is important that the joint at the heel of the point rail should be kept in fair surface. If this joint is permitted to get low when the point rail is humped it leaves the track in rough condition, and if the point rail is not humped a low joint at the heel tends to cause the stock rail to spring up and stand higher than the rear portion of the point rail. An objection urged against the humping of the point rail is that it forms rough surface in the track and gives rise to a lifting sensation when riding over it at high speed. On a goodly number of roads the practice is not followed, but the effect of badly worn tires on trailing point switches is well worthy of consideration. Derailments have been known to happen from the fouling of the stock rail by badly worn wheels, where the point rail was not high enough to lift the wheel tread clear of the stock rail. To provide against this danger without putting the point rail out of surface it is the practice on the Burlington & Missouri River R. R. to plane down the stock rail $\frac{1}{4}$ in. for a distance of 2 ft. covering the fouling point.

The two point rails are connected by tie rods (*R*, Fig. 142), the one nearest the point ends being known as the head rod or "Rod No. 1"; the rod farthest from the point ends is sometimes called the "heel rod." The head rod, whether the switch stand connection comes at the end or not, is usually extended both ways under the main rails, to provide against the possibility that the point rails might in some manner be lifted. In some instances a "carrying bar" (2 ins. x $\frac{3}{4}$-in.) bent to set under the head rod, across the tie spacing, is spiked down near each end of this rod to hold it to place in case it should become disconnected from either point rail. In some designs of point switch, now considerably out of date, the solid ends of the tie rods are formed into an "L" or a "T" and bolted to the web of the point rail direct; but such an arrangement is not approvable, for the reason that the creeping of the rails brings a strain upon the rods and is liable to break them off at the shank. In general practice the connection with the point rail is usually made by means of a T or L-shaped lug or clip bolted to the web of the rail and hinged to the tie rod. It may be stated as a principle to be followed generally that the tie rods should not be rigid against creeping rails. If the tie rods are flat horizontally or of round section they should be hinged to the point-rail fastenings, but if the rods are of flat section and stand edgewise vertically, hinged connection with the fastenings is not so necessary, as the spring in the rods will take care of a considerable amount of creeping without dangerously cramping the parts. It may be well to explain that the hinging of horizontally flat tie rods is precautionary rather than always necessary. As the lead rails from the heels of both switch points run to the frog, it is not possible, where there is proper construction, for one point rail to be pushed out of true with the other by creeping steel. If, however, the switch is used with a spring-rail frog that is not provided with an effective anti-creeping attachment, or if the closure rails of the turnout lead are not cut to a proper fit, leaving an excess of open space at the joints, the creeping of the frog is likely to drive one point rail ahead of the other.

An advantage claimed for tie rods which are edgewise vertically is that they stand the rigid way to oppose canting of the point rails. Tie-rod clips should preferably be attached to the web of the point rail, as connection with the flange cannot be made so secure or so rigid against canting of the rail; and as the bolts are in shear against a thin bearing the vibration of the parts under traffic tends to wear the bolts, enlarge the holes and cause the rods to loosen and rattle. It is a good feature of switch design to crook the clips or the ends of the tie rods so that the latter set lower than the tops of the ties, where they will have protection against derailed wheels or anything dragging. On the Michigan Central R. R. the usual practice of placing the switch rods as low as, or below, the tops of the ties is followed, and then 2x10-in. oak blocks with the corners chamfered are spiked to the ties, on either side of each rod, to protect it from derailed wheels and dragging parts. When in this position and creeping of the lead rails takes place, it is necessary to keep close watch of the rods. If they become shoved against the ties the switch will not work freely until the ties are moved or the lead rails are driven back.

One of the most frequently discussed questions concerning the design of split switches is in reference to the number of tie rods. In the largest practice the preference has always been for four tie rods on 15-ft. point rails. Late years there has been some tendency to decrease the number of rods or tie bars on point switches, but the change has not been general. Tie rods are some hindrance to the tamping of the switch ties and also to clearing the switch of snow and ice, but otherwise they are not objectionable. They serve to brace and stiffen the point rails, and as their number is decreased reinforcing straps and stop blocks are used to make up for the loss in stiffness. In yards a single tie rod connecting reinforced point rails, or one or two tie rods without the reinforcement are customary arrangements, but for main track it is essential to have at least two rods, for the reason that if the head rod should break or become disconnected from one of the point rails there would be nothing to hold the point rail to place. Where two rods are used and the first one breaks or becomes disconnected the second one will still perform the necessary functions. In the absence of reinforcing straps four tie rods will serve to hold the pieces of a point rail in place in case of a break, and have frequently done so. The number of tie rods depends to some extent upon the length of the switch points. On point rails longer than 18 ft. it is quite customary to have five rods, and in some instances five rods are used on 18-ft. points (Fig. 142 A). In the matter of tie rods with some of the English railways a distinction is made as to the character of the switch, three rods being used on facing switches and only two rods on trailing switches.

So far as the determination of the lead distance and the running of the lead curve are concerned, the throw of the point switch is unimportant. As already explained, mathematically, the turnout measurements and curvature depend upon the number or angle of the frog and the length and spread of the point rails. The throw, however, must be sufficient to keep the free end of the open point well clear of the wheel flanges. In practice the throw ranges from 3½ to 5½ ins., but most frequently it is 4½ ins.; 4 ins. is about the least approvable distance unless guard rails are used ahead of the points. On roads where both point and stub switches are in service it is well to have the throw of the point switches the same as the standard throw for the stub switches, as then the switch stands will be interchangeable. As a matter of economy there is some advantage in the maximum throw for point switches, as increase in the width of the flangeway lessens the side pressure of the wheel flanges along the rear portion of the point rail (say from some point near the heel to the point where the planing runs out), and consequently there should be less straining of the rods and fastenings, less wear on the connections and less frequent repairs.

Switch-Point Guard Rails.—If the throw is less than 4 ins. guard rails should be placed in advance of the points, as shown at *G* in Fig. 142. These guard rails serve to keep the flanges of loose or improperly-gaged wheels away from the open point when they approach from the facing direction, and also to protect the points from damage by dragging brake beams, etc. The ends of such guard rails should be placed as near the ends of the point rails as safe clearance will permit, taking into consideration the extent of the rail creeping, and the flangeway in this case need not be as narrow as with guard rails opposite frogs; 2 or 2⅛ ins. is close enough. It might be well to again emphasize the importance of using a guard rail of proper length, say not less than 15 ft., especially because so many seem to think short guard rails in a place like this are sufficient. Except under extraordinary conditions short guard rails should not be used anywhere. For its own security alone the guard rail should not be shorter than the length stated. A guard rail should always be laid with the expectation that it is going to stay. The short insecure guard rails laid in front of facing-point switches have been the cause of derailments and wrecks, the accident usually happening in this way: A derailed wheel or part of a car truck dragging in the track would strike the end of the guard rail and drive it ahead, causing the flared end of the guard rail to force aside the open point rail, which would pull open the point rail on the opposite side and split the train. It is therefore very important that guard rails in front of switch points should be made secure against dislodgment by end blows. As a means to this end the flange of the guard rail may be notched and slot-spiked and the end farthest from the switch point should be sloped down to the ties (Fig. 98).

Guard rails ahead of split switches are not used as much as formerly, and if used at all it is frequently the case that only one is laid, and that ahead of the open point when the switch is set for main line. In some cases where only one such guard rail is used, however, it is made 30 ft. long and placed ahead of the closed point, to guard the wheels from the end of the point rail which is closed when traffic enters the switch, and to afford additional security to trains coming out of the switch at good speed, until the trucks are swung into line with main track. Where heavy traffic passes out of a siding, and particularly where the turnout curve is sharp, it will usually be found that the wheel flanges cut into the through rail in front of the switch and cause abnormal side wear. This action is due to the resistance of trucks to slew under heavily loaded cars that are down on the side bearings, and if there is a guard rail on the stock-rail side set to a proper flangeway (1¾ ins.) it will take the wear which otherwise would have to be received by the through rail. One of the roads whereon the matter of switch-point guard rails has received careful study is the Philadelphia & Reading Ry. The practice there is to place a guard rail in front of the open point at all facing switches, and at end of double track a guard rail is laid in front of both points. At the ends of lay-off sidings that are much used and at other points where switches are used trailing as a rule, a guard rail is placed in front of the closed point, to prevent side wear to the through rail from wheels trailing out of the switch. Guard rails so placed are laid to a flangeway of 1⅞ ins. At ordinary facing switches they are laid to a flangeway of 1⅞ ins., and at facing-point junctions the flangeway is made 2 ins. (for standard gage). The guard rail in any case is 9 ft. long, with the end 3 ins. from the switch point, and the rail is well spiked and braced. At the switch-point end the guard rail is flared to an opening of 4 ins., in a distance of 1 ft., and at the other end it is flared to an opening of 5 ins., in a distance of 5 ft.

At all facing-point or "point-on" switches leading to the outside of curves (which of course includes all such switches on single track) there should be a guard rail of good length ahead of the open point, on the inner side of the curve, set at standard guard rail distance, so as to act in restraint of the outward tendency of the wheels and protect the end of the outer point rail from undue wear. The end of the guard rail next the point should be curved rather more suddenly than is usually the case, so as to guide the wheels as long as possible before they reach the end of the point rail. It should not be curved inward past the line of the guard side of the open point; to be on the safe side it is well to keep it slightly within that line. In a case of this kind the end of the point rail should be well shielded behind the bend of the stock rail.

In order that the guard rail may be laid to fully protect the facing point on the outer side of the curve until after the wheel is well past the end of the same, it is quite largely the practice to have the point rail on the outer side 2 to 3 ft. longer than, and extend that distance in advance of, its mate, so as to make room directly opposite for the guard rail. The guard rail opposite the extended end of the long point rail, if set to a proper flangeway, will relieve the end of that point rail from wear. The connecting rod is attached to the long point rail near the end and slides through a slotted block or guide of some kind under the base of the rail opposite. To obtain the necessary strength for the extended end of the long point that rail should be reinforced.

The Vaughan point switch consists of long and short point rails gaged to prevent cars from "splitting" or "straddling" the switch. Referring to Fig. 142A, there is a pair of 18-ft. switch points with five tie rods, of the ordinary construction, except that the planing of the head of the main point rail is run out bluntly 2 ft. 9 ins. in rear of the point end; the web and base of this point rail, however, are carried the full length, or to a point opposite the end of the mating switch rail. At the end of the short point the gage out to out of point rails is 4 ft. 6¾ ins., which corresponds to the standard distance from the back of a wheel flange to the gage line on the flange fillet of the opposite wheel on the same axle. It is thus clear that after a wheel has taken either side of the long point the wheel on the opposite end of the same axle must necessarily take the same side (right or left) of the short point; it is impossible for a pair of wheels to take both sides of the points (reference being had to the wheel flanges, of course). In other words, if a wheel takes the flangeway side of the long point it is impossible for the mating wheel to take the flangeway side of the short point; and, after a wheel has taken the gage side of the long point the mating wheel is compelled to take the proper side of the short point. With the points in any position the wheels cannot get off the rails. Should the short point by misadjustment, accident or carelessness in throwing the switch remain slightly open, the wheel flanges cannot get behind it, as the flange of the mating wheel, behind the long point, will crowd it over and complete the throw of the switch. An extra heavy tie rod strut is used at the short point to preserve the proper spacing of the point rails. The throw of the switch for standard-gage track is $3\frac{1}{2}$ ins. and the long point rail, from rod No. 2 to the end, is slightly curved. As the service end of the short point rail ordinarily comes about $3\frac{1}{2}$ to 4 ft. in rear of the bend in the stock rail, the gage of the track directly at the

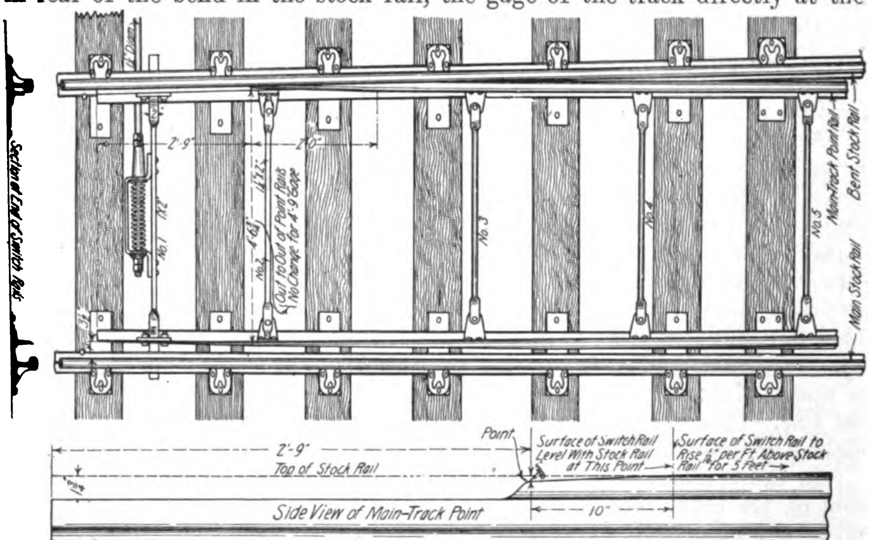


Fig. 142 A.—Vaughan Split Switch, West Jersey & Seashore R. R.

short point is necessarily wide, being about 4 ft. $9\frac{3}{4}$ ins., or $1\frac{1}{4}$ ins. wider than standard. The tapering of the short point rail from the general alignment is made in a distance of 2 ft., as shown, so that the widening of the gage extends only a comparatively short distance, and cannot affect the riding of any switch turning from tangent or from the inside of a curve. When the turnout is from the outside of a curve the best alignment for the outer main-track rail is obtained by using the long point for main track, or the reverse of the arrangement shown. This arrangement does not afford the full protection to be had from this style of switch when used normally, but still provides a switch which cannot be "straddled." Whenever it is feasible with facing-point switches, the short point is used for main track, as shown, in order to have the long point act as a guard rail for it. It is therefore customary to order these switches made right or left hand. The bend in the stock rail comes at the usual distance in advance of the switch points, or about 16 ins. ahead of the extended base and web of the short point rail. In other words, a pair of points of ordinary construction can be lifted out, and a Vaughan switch of equal length dropped into the same place will fit without further bending or changing of the stock rail. Referring to the side view of the short point rail, shown in the figure, it will be noticed that the web portion which extends beyond the service point, is $1\frac{3}{4}$ ins. lower than the top of the stock rail. The service end of the short point rail is $\frac{5}{8}$ in. lower than the top of the stock rail, and the top of the rail in rear of this point is planed back on a slope which rises to a level with the top of the stock rail in 10 ins. and to a point $^5/_{16}$ in. above top of stock rail in a distance of 5 ft. further, so as to carry the outer flange of badly worn wheels clear of the fouling point in the angle where the split and stock rails separate.

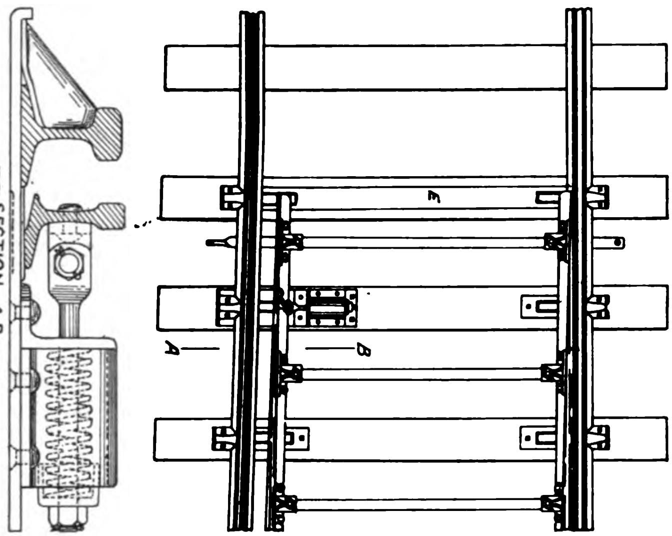
The protection which these switches afford has been thoroughly demonstrated by the large number of switches in practical use and also by tests in which the switch was only partially thrown and left in various positions while cars were thrown against the points. Special tests were also made by running cars against the points of the switch with the main-track point rail held open fully $\frac{3}{4}$ in. by blocks inserted between it and the stock rail, as would be the case if the switch was blocked with snow or with a bolt, piece of ice, or other obstruction dropped from a car. In every case all the wheels safely passed the open point. The main tracks of the Atlantic City division of the West Jersey & Seashore R. R. were equipped throughout with these switches when 100-lb. rails were laid, and a large number have been used in new work and for renewals in yards. There are also a large number of the switches in use on the various lines of the Pennsylvania R. R. east of Pittsburg and Erie. The designer of this switch is Mr. D. F. Vaughan, supervisor with the West Jersey & Seashore R. R., the same gentleman who designed the Vaughan spring-rail frog (Fig. 86) and the Vaughan sliding spring rail frog for yard use (Fig. 88).

Wherever the connecting rod is coupled rigidly to the head rod and to the switch stand, an accurate throw of the stand, to correspond to the throw of the points, is required; any lost motion from wear of bolts or other parts will leave the points loose. Loose points in facing split switches act in the same way that lip does in stub switches; as soon as the point becomes loose enough to catch a flange the wheel is derailed. The danger from this source is the more imminent where the switch turns to the outside of a curve, and to avoid trouble in such locations a switch point lock, otherwise called a "deadlock," is sometimes used on the main point and stock rail. Referring to Fig. 141, a shaft (*A*) is secured to the headblock by hangers (*C*) and is turned by a lever (*B*) placed opposite the switch stand. The shaft is crosswise the track, under the stock rail, a short distance back of the extreme point. This shaft has two lugs (*L*) which, when the shaft is turned up, straddle the point and stock rails and hold them securely together regardless of the connecting rod. The lugs should be beveled back a little from their ends so as to engage the rails without catching. By attaching the switch lock to a chain just long enough to reach the lever *B* in its raised position the lever is held up while the switch is locked and the shaft is kept from revolving and disengaging the lugs from the rails. When opening the switch the lever must of course be turned down, but before locking it again the lugs must necessarily be brought to engage the rail in order to get the lever up and the lock to its place. The switch cannot be locked, therefore, unless the point is resting against the stock rail. On double track, at any rate, some such locking device should be placed on all facing-point switches. It will hold the switch securely in place in event the connecting rod should break or become disconnected, or the switch stand be broken down by a mail sack or baggage thrown from a moving train, or by a derailed car running out of line, or by a piece of lumber projecting from the side of a car, or by an unfastened car door hanging out, or in any other manner. With the closed point rail locked in this manner the dividing or derailing of a train, which sometimes happens when a derailed wheel strikes the open point rail and throws the switch under the train, can also be avoided. The Coughlin-Sanford point lock is described in §221.

An automatic switch point lock devised by Roadmaster W. E. Emery, of the Chicago & Northwestern Ry., has been used on that road. Referring to Fig. 155A, there is a fixed automatic padlock (*B*) attached to the outer flange of the stock rail by means of a short heavy bar (*H*) slotted for the hasp(*F*). The hasp is attached to the side of the head switch rod and when the switch is thrown to the main position the hasp enters the padlock and secures the point rail. The open position of the switch is indicated by the dotted lines. In opening the lock an ordinary switch key is used, as in any other lock, the lock automatically holding itself open until the switch is thrown over for the side-track. When it is desired to close the switch the point rails are simply thrown over, as ordinarily, and the lock closes automatically. When it is desired to render the lock inoperative for the purpose of switching cars the switch key is put into the lock, turned half to three-quarters of the way round and left in that position until the switching is done; the key is then removed before the switch is thrown for the last time. In designing this lock Mr. Emery had in view that switches provided with the same would not need an ordinary lock on the switch stand, and that the device could be used in combination with distant or home signals.

In point switches having plenty of throw, lost motion due to wear of parts or spread of gage, may be taken up temporarily by placing washers between the head switch rod fastening and the point; that is, in case the fastening is bolted to the web of the point rail, as shown at *M* in Fig. 142. The point rails are thereby spread apart, and as the shape of the fastening is usually such that it is most secure only when tightly bolted against the web and flange of point rail, the practice should be resorted to only as a temporary expedient. Sometimes trackmen take up lost motion by setting in the through rail or stock rail near the point of switch and bracing or respiking the same, but unless the main rails are wide for gage in the first place, the practice is not to be recommended, since it interferes with the gage and makes an unsightly jog in the alignment. Close gage should be maintained at the bend of the stock rail. It is usual to brace both main rails at this point to hold them to gage against the force exerted in throwing the switch tightly home, and also against the side pressure of the wheels in taking the switch. A very secure device quite frequently employed for this purpose is a stub-switch rod placed at or just in advance of the bend in the stock rail. A long bolt passing through holes drilled in the webs of the stock rails just ahead of the point rails has also been used to maintain the gage, but as such a device stands up clear of the ties where it is liable to be caught by dragging brake rigging, or cut by derailed wheels it is not so desirable as the switch rod. A long sliding plate or "gage plate" at the ends of the point rails, continuous under both main rails, is a good device and is now quite commonly employed. This plate may be turned up at the ends to serve as a backing for braces, as is the case with plate *E*, Fig. 143, or there may be seats planed out for the rails, as at *A*, Fig. 144.

Adjustable Switch Rods and Point Rails.—An arrangement for taking up lost motion, so as to hold the points closely to either main rail, or to adjust the throw of the points, sometimes made necessary by wear of parts or variation in switch stands, is the adjustable head rod, of which there are many patterns. On the Transit split switch (Fig. 144) use is made of an adjustable connection between rod and fastening, the points being spread apart or drawn in accordingly as the rod is advanced or moved backward along the diagonally-set row of holes in the fastening clip *B*. The Weir company accomplishes the adjustment by means of a turnbuckle placed in the head rod (*G*, Fig. 145). Both threads of this turnbuckle are right-hand, so that the adjustment cannot be affected by meddlesome persons who might tamper with the buckle. To adjust the points it is necessary to first disconnect the head rod from the point rail by removing the bolt from the fastening lug to which this rod is attached. This company has another device in the shape of a flat head rod (*H*, Fig. 145) in two pieces, one of which is drilled with bolt-holes at $1\frac{1}{8}$ ins. centers, and the other at $1\frac{1}{4}$ ins. centers, each rod being provided at the end with a slotted hole. Owing to the difference in the drilling of centers each change makes a difference of $\frac{1}{8}$ in. either in the lengthening or shortening of the head rod. When adjustment is necessary the bolts in the slotted holes are loosened, the center bolt withdrawn, and the rod moved as occasion requires—lengthening or shortening. It is possible to obtain any adjustment up to $2\frac{1}{2}$ ins., thus providing for widening



—SECTION A-B—

Fig. 143.—Spring Split Switch.

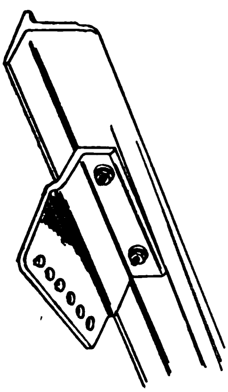
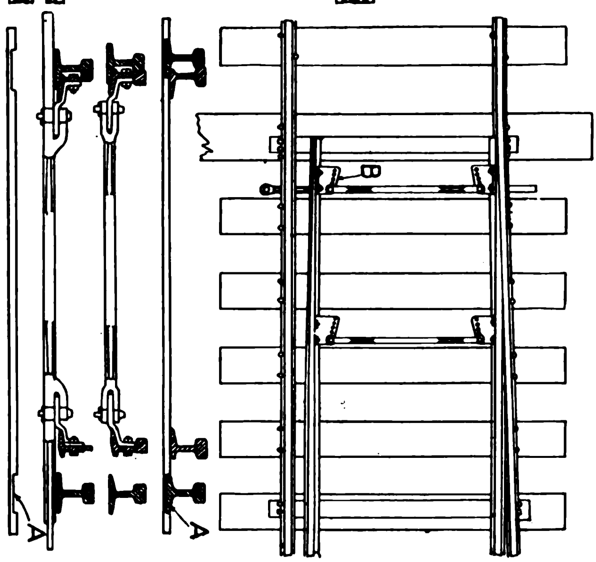


Fig. 144.—The Transit Split Switch.



of gage and the difference in throw of switch stands. Another arrangement working on the same principle is by a differential drilling of the tie rod and the switch-point fastening or lug, as shown by Fig. 146. The lugs are drilled at 1¼ ins. centers and the switch rods at 1⅛ ins. centers, and by this difference in drilling an adjustment of ⅛ in. is obtained at each change of position. Either switch rail may be adjusted independently of the other, or both may be adjusted at the same time. It may here be noticed that an adjustment which takes place in the rod itself, between the point rails, affords a means for adjusting one point rail only, and that is the one on the side opposite the connecting rod; hence the advantage of an independent adjustment for each point rail.

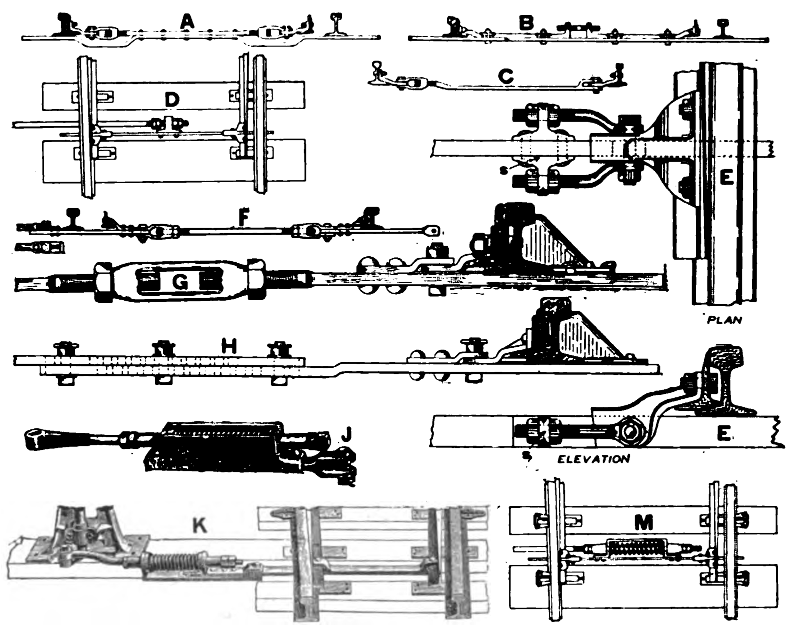


Fig. 145.—Switch Point Adjustments and Connections.

Device *F* (Fig. 145) operates in a manner similar to that of *G*. In device *B* the adjusting bolt passing through the two opposing lugs has threads cut right and left on its two ends, and the sliding bars attached to the point rails are slotted for the bolts which secure them to the head rod. Devices *A* and *E* permit of independent adjustment on either side. The former has the clevis adjustment, which is accomplished by removing the coupling bolt and twisting the turnbuckle-ended clevis. In the latter device the fastening lug operates as a sliding clip on the rod and it is changed by adjusting the nuts on the horizontal bolts passing through the fixed yoke *S*. A similar device is shown in Fig. 148. With device *D* the throw of the stand usually exceeds that of the points, the arrangement requiring that the connecting rod should slip loosely through the hub on the tie rod. By properly setting the adjustable jam-nuts the switch points can be thrown firmly against the stock rail at either side, it being possible to increase or diminish the throw of the points as desired or to compensate for any excess of throw of the stand over that of the switch. The standard device of the Union Switch & Signal Co. for adjusting the throw of switches is quite similar and is shown in Fig. 247.

On the Chicago & Northwestern Ry. a head-rod adjustment is effected by dividing the rod between the point connections and joining the parts by means of a sleeve coupling. For this purpose a piece of heavy pipe 7½ ins. long is welded to the end of one piece of the flat (¾ in. x 2 ins.) head rod and tapped out to receive the threaded rounded end of the other piece, the screw being 1¼ ins. in diam. Engraving *K*, Fig. 190, shows the application of this means of adjustment to the tie bars of a movable-point frog. The Elliot "key wedge" adjustment is shown by Engraving *H*, Fig. 112. The head rod forms the only tie rod between the reinforced switch points, and this head rod has two slots similar to those of a stub-switch rod, into which are fitted pieces of T-bar to which the switch points are attached.

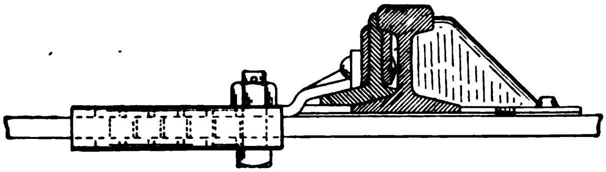


Fig. 146.—Weir Switch Point Adjustment.

The switch-point connection to the T-bar is by means of two bolts (one each side the head rod) through a filler block and an adjusting wedge *W*. The wedge is drilled with a series of holes properly spaced for the two bolts, and adjustment is effected by taking out the bolts and moving the wedge out or in, each movement over the distance of a hole spacing changing the gage ⅛ in.

Figure 147 shows the parts of the Eccentric switch rod adjustment and the application of the same to the head rod and remaining tie rod of the "Gauge" split switch. This adjustment, devised by Mr. Axel A. Strom, is effected by means of an eccentric washer at the connection of the tie rod with the clip fastening on the switch point. As shown in detail at the right in the figure, there is a boss on the under side of the washer which fits a circular opening in the clip. The hole for the connecting bolt is eccentric with this boss, and by rotating the washer the position of the point rail may be moved from or toward the tie rod, as desired. In order to lock the washer in the adjusted position it is provided on the under side with two stop studs which engage with holes on the clip. The connection with the clip and washer is between the jaws of the tie rod, and to adjust the position of the point rail it is necessary to disconnect the tie rod and reset the washer. On the clip there are 14 locking holes, corresponding to as many positions for the adjusting washer, and each successive position of the washer is adapted to a variation of $^1/_{16}$ in. in the gage of the switch points. It will be noticed that the consecutive numbers indicating the different positions of the washer alternate from side to side, the purpose of the arrangement being to use the same locking hole for two positions of the adjusting washer, thus making it possible to arrange within small compass a sufficient number of holes for an adjustment of desired fineness. In manipulating the washer for successive positions of minimum change, as when setting the points by trial, it is first turned to an assumed position; then in the opposite direction for the position next in sequence; back again beyond the first position, for the third trial; in the contrary direction, beyond the second position, for the fourth trial, and so on. The Bristol adjuster

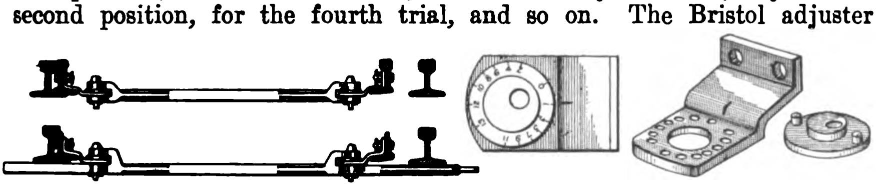


Fig. 147.—Eccentric Switch Point Adjustment.

works on a similar principle. It consists of a washer of octagon shape drilled eccentrically $^3/_{16}$ in. This washer is $\frac{1}{2}$ in. thick and fits into an octagon hole in the clip. To adjust the switch rail the clip is removed from between the jaws of the switch rod and the washer is taken out and turned the required amount.

Notwithstanding that rigidly connected switch points are still preferred on several of the large railway systems where track engineering has been closely studied, the advantages in the use of means for adjusting the point rails of split switches are well established. Adjustable switch rods and point rails are now very commonly used, being standard on perhaps a majority of the railroads of the country, and they are growing in favor. One objection urged against the use of these adjustment devices in general is the incompetency of section foremen, it being feared on the part of some railway managements that means for adjusting the switch rails might lead to ignorant or careless use of the same by men in charge. Some maintenance-of-way officials also profess to apprehend that in case the gage should widen at the stock rail their foremen might take up the lost motion by adjusting the switch points in place of regaging the rails. It is perhaps unnecessary to remark that men who are not equal to the adjustment of split switches might be expected to get into trouble with some other matters over which section foremen usually have charge; and, at best, they must be poor support to a roadmaster. The objection that adjustment devices give meddlesome persons opportunity to tamper with the switch carries but little weight, for persons maliciously inclined may find other ways for doing harm which are just as convenient. A weighty argument in support of adjustable switch points is the commonly observed fact that unless means of adjustment are provided the section foremen will improvise means of their own, placing nut locks, washers, telegraph wire, etc. between the clips and the web of the point rail. It is also to be considered that adjustment devices come handy when switches or stock rails are being renewed. Point switches made to the same standard drawing are not always closely enough alike in essential dimensions to fit the main rails in the same manner; and rails nominally of the same section are liable to vary slightly with wear of the rolls. In renewing a split switch with one having rigidly connected point rails or with no means of adjusting the throw of the same it is usually necessary to regage the main rails, reset the switch stand or tamper with the clips. It is to some extent the practice to interchange the point rails of switches, taking a worn point from the open side of one switch and exchanging with that of a switch that is not used a great deal, or the worn point from the closed side of one switch and exchanging

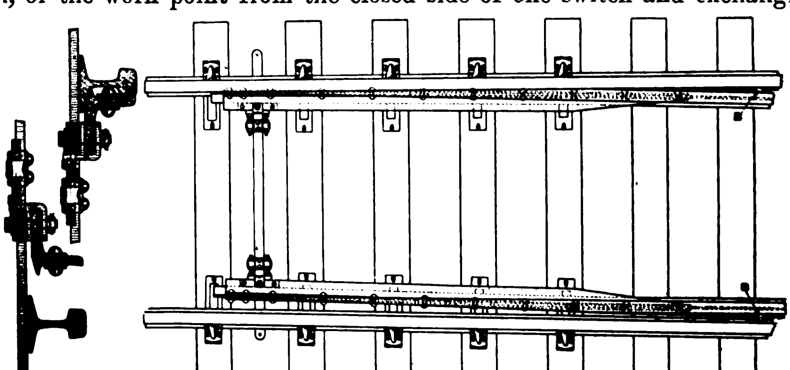


Fig. 148.—Reinforced Split Switch with Adjustable Points.

with the open point in another switch turning in the opposite direction that is not much used. Where this is done a means for adjusting the point rails is a decided convenience.

On some roads the matter of switch point adjustment receives very careful attention, as on the Santa Fe Pacific R. R., where the standard practice is to adjust the points so close to the stock rail that a sheet of ordinary writing paper between the two will be torn before it can be pulled out. As to the merits of the various devices for this purpose it may be said that several of those in service give satisfaction. Not a few prefer to use rigidly-connected points with an adjustable rod connecting the same with the switch stand, or to have the means of adjustment at the coupling of the connecting rod with the head rod. A fault sometimes charged against screw adjustment devices is that the threads wear and fail to hold, and another difficulty complained of is that where such devices are exposed to the drippings from refrigerator cars the turnbuckles or nuts soon become rusted fast by the brine and rendered hard to turn or adjust. In a committee report to the Roadmasters' Association of America, in 1900, it was recommended that devices for adjusting split switches should permit the adjustment of both point rails and that the limit of the adjustment should be restricted to the minimum throw of the points.

Reinforced Switch Points.—Switch points in main track should be reinforced, the necessity arising not from lack of strength, but from a demand for some means of holding together the disconnected parts in case the point rail should break. A record covering 950 point switches on the Chicago, Burlington & Quincy Ry. shows an average of one breakage every two years, the break usually occurring at a flaw in the rail. From various reported cases of broken switch points it seems that breakage occurs most frequently between the second and third tie rods, or about at the point where the switch rail begins to carry the full load when the wheels come facing. It is usual to reinforce both the main and turnout point rails, and the most common form of reinforcement is a wrought iron bar or strap $\frac{1}{4}$ to $\frac{5}{8}$ in. thick riveted to the web of the rail with $\frac{5}{8}$-in. or $\frac{3}{4}$-in. rivets, preferably on either side, as appears in Fig. 145 (Engravings *G* and *H*), Figs. 146 and 148. In some instances the straps are bolted on, with the intention of using them on a new set of switch points when the old ones become worn out, but riveting is the more secure and the preferable method. In extensive practice switch points are not reinforced farther back than the planed portion of the rail, but to afford desirable security the reinforcement should extend the whole length, or as far as the heel splice. Without a reinforcement a break in the switch rail anywhere back of the last tie rod is a very dangerous thing. For switches used in yards and in tracks where fast trains do not run it is not considered necessary to reinforce the point rails.

Figure 148 shows the Pennsylvania Steel Company's manner of reinforcing switch point rails. On the flangeway side of the point a plain, flat wrought iron bar is used for a reinforcing strap, while on the gage side there is an angle bar with a 4-in. horizontal leg, to which the switch rod is attached. As the three pieces are securely riveted through and through a high degree of lateral stiffness is imparted to the rail. The adjustable head rod is similar to type *E*, Fig. 145, and permits either point to be adjusted. The Wharton company controls the patent on a switch point reinforcement consisting of a channel. The back of the channel is riveted to the web of the switch rail and the switch rod connection is made by means of a pin through the flanges of the channel.

In the Channel split switch (Fig. 149), the standard switch of the

Atchison, Topeka & Santa Fe and other roads, each point rail is reinforced by a 10-ft. piece of 45-lb. rail, called a "supporting rail," the two being securely united by bolts and cast separating blocks, at such a distance apart that a foot guard is unnecessary. The head rod is attached to the supporting rails by the ordinary stub switch slot connection, and is held fast against slipping along the rail by the retaining block *R*. As may be seen, there are adjustment holes in the web of the supporting rail, thus permitting the rod to be moved up on the flared end, so as to take up wear at the points and lost motion in the connections. The gage plates *P* extend entirely across the track, forming slide plates for the point and supporting rails, and have seats planed out at the ends to receive the stock and through rails. As there is no wear on the supporting rails, and as they are the same size (45-lb. section) for point rails of all sizes, all that is required in renewing the switch is to bolt on new point rails. Such is a convenient arrangement, especially when the track is being relaid with steel of larger section. As the supporting rails make the switch very stiff it is not an easy matter to lock up the switch stand with an obstruction between the point rail and stock rail. With the ordinary split switch it sometimes happens

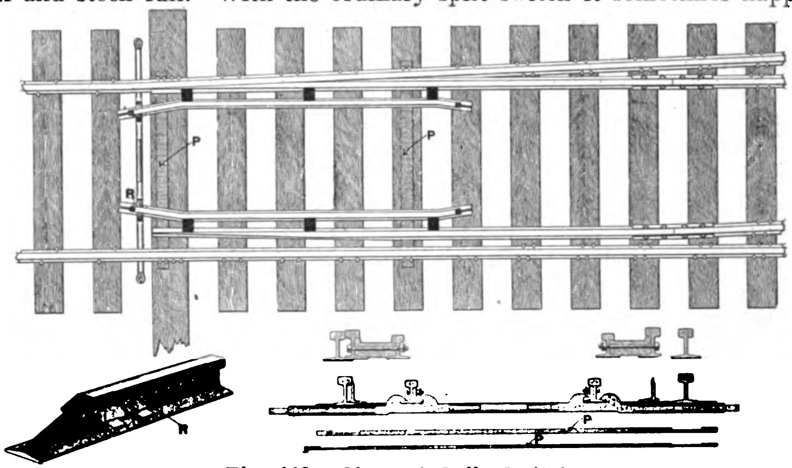


Fig. 149.—Channel Split Switch.

that the point rails will bend and permit this to be done. To prevent passing objects from catching on the supporting rails the ends of the same are sloped down to the base, as shown. As with the Elliot Key-Wedge Adjustment switch (Engraving *H*, Fig. 112), so with the Channel switch, the point rails are firmly held against any force tending to cant them and bend the clips or tie-rod fastenings. The "Curve" split switch (for turnouts to outside of curve) has a long point for the main switch rail, with a "supporting" rail of the Channel switch type; and a short point rail for the through-rail side, with a guard rail in front of the same protecting the extending end of the long point rail on the opposite side of the track. The short point has no supporting rail and the tie rods and clips are like those used on the Transit switch (Fig. 144).

A stop block or stop lug (*B*, Fig. 148) is a cast or bent piece bolted either to the point rail or to the stock or through rail to back up the point rail when it is thrown to that side. It is of sufficient thickness to block the space between the two rails when the switch is thrown to that side, and on 15-ft. points it is usually placed midway between the heel and where the planing starts. It is particularly serviceable on the main point of a switch which turns to the outside of a curve, on switches with less than four tie rods and on switch points longer than 15 ft., but it is a good plan to use it on all point switches. On extra long switch points it is customary to use two or more stop lugs. On the Michigan Central R. R. switch points 22 ft. long, used in connection with No. 14 frogs, have five tie rods and three stop blocks, and are reinforced both sides back to a point 2 ins. from the heel splice. To hold the rail in line in case of breakage between the reinforcement and the splice there is a flat bar of iron, called an "S-brace," fitted over the base of the point rail, butted against the web of the same at the 2-in. space and spiked to the tie. Point rails 24 ft. long used with No. 15 frogs at end of double track on the Chicago, Burlington & Quincy Ry. have five rods, and stop blocks, but the rails are not reinforced. The point switches for track of 100-lb. rails on the Duluth & Iron Range R. R. are 20 ft. long and have five tie rods spaced 3 ft. 2 ins. apart, the head rod coming 9 ins. from the point end. On each point rail there is one 3x⅝-in. reinforcing bar secured to the web on the flangeway side, with ⅝-in. rivets. This reinforcing bar is 6 ft. 9 ins. long, and extends to the third tie rod. The switch has no stop lugs.

The pushing of switch points by creeping rails leads to repair work sooner or later, usually to move the headblock and switch ties out of contact with the switch rods. It is desirable, therefore, to hold this creeping in check, and as both point rails lead to the frog the best way to go about it is to slot-spike the four sets of splice bars at the ends of the frog, the splices at the heels of the point rails and the intervening splices on the lead rails. In addition to this it is frequently the practice to bolt on a twisted anchor strap to the inside splice bar at the heel of each point rail and spike it to the three or four ties over which it extends. This is about all that can be done, conveniently, and unless the creeping is bad it will usually accomplish the purpose. Where creeping is bothersome it usually does more harm than good to anchor the heels of the switch points to the through rail and stock rail. This is sometimes done by means of a cast heel block or filler between the two rails, bolted through and through and used in lieu of a foot guard. In some places where such devices have been used they have given considerable trouble by causing the creeping rails to throw or crowd the joints out of line. The same results have also been experienced with spacing devices to hold the heel of the point rail at the proper distance from the stock rail. An arrangement sometimes used for this purpose consists of bolts through both rails with gas pipe collars to hold the rails at the proper distance apart. A better arrangement where creeping is bothersome is a shouldered tie plate with seats at the proper spacing for the two rails. The rails may then creep unhindered but will be maintained at the proper distance apart. As a matter of fact the creeping of the through rail or stock rail, if permitted to do so freely, is seldom bothersome. The creeping of the through rail, cannot affect the adjustment of the point rails, while with the stock rail a moderate amount of creeping may not require readjustment of the point rails, much depending upon the relative position of the bend in the rail.

In this country it is customary to bolt up the heel splice of point rails as tightly as at ordinary joints. On some of the foreign railways this splice is left sufficiently slack to permit the switch rail to work freely, or without bending the splice bar, while in other instances, as with the Netherlands State Railways, the point rails are hinged to heel castings without splicing.

Automatic Point Switches.—The term "automatic," as applied to point switches or switch stands, has reference to the action of the point rails for a car or train trailing the switch when it is set the wrong way. The wheel flanges crowd the points over against the direct or indirect tension of a spiral spring, so that no damage is done to the point rails or other parts, as would necessarily result were the connections rigid throughout. The term "safety" is sometimes used in the same sense, but its full meaning, as applied in every case, should be interpreted advisedly. Automatic action of the switch may be had by the use of a spring connection with the head rod, by a spring connecting rod, or by an automatic stand. The first-named device answers to the description of the Lorenz spring, contrived at an early date, being perhaps the oldest device, and certainly one of the best known devices, for permitting the automatic working of split switches when such are set the wrong way for trailing movements through them. It is shown as Engraving *A*, Fig. 105; Engraving *M*, Fig. 145; and in Figs. 142A and 157. A spiral spring is placed between two lugs or within a frame, on the head rod, and the connecting rod instead of being attached directly to the head rod is made to operate the points by acting on this spring. The rod is passed through the coil of the spring and through holes in the lugs, and acts against either end of the coil (depending on which way it is thrown) by means of a collared spool or sleeve backed by jam-nuts on the rod. If the throw of the stand exceeds the throw

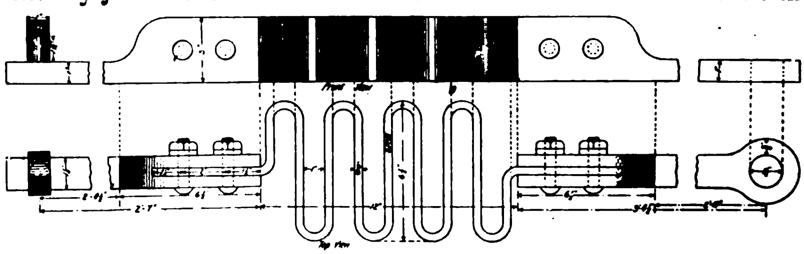


Fig. 150.—"P. O. D." Spring Connecting Rod, B. & M. R. R. R.

of the points (as it should with this device) these nuts may be so adjusted that some of the throw of the stand or connecting rod must be taken up in compressing the spring. Lost motion can thus be taken care of, the point rails being held firmly against either side to which they are thrown, and if trailed the wrong way they will yield to the wheel flanges and then return to the position in which they were last set. As a precaution against entire failure the spring is sometimes composed of two coils—one within the other—the probability that both springs will break at the same time being less, it is thought, than of the breakage of a single spring heavier than either. For security on facing-point switches springs attached to the side of the head rod should be placed on the side facing the frog.

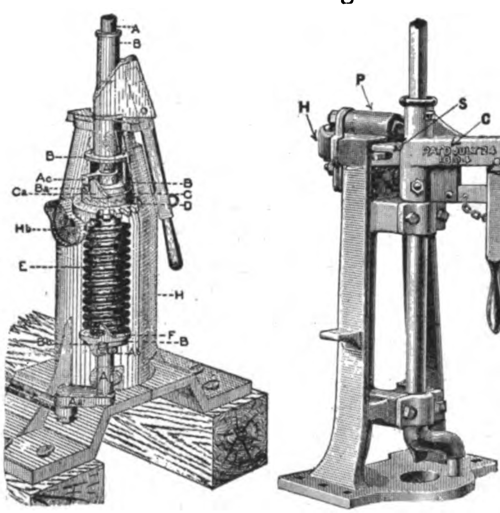
An objection raised against the use of an automatic switch on single track or an automatic facing-point switch on double track spring connected in the main-line position, in either case, is that, with hard-packed snow or some small obstruction between the point and stock rail it is possible to throw the stand completely without bringing the point rail quite up to its place. Moreover, should the spring on an automatic facing-point switch break the latter would at once become a dangerous affair. The same objections apply, of course, to spring connecting rods and to such types of automatic stand as can be locked without throwing the points clear home; also to any stand designed to hold the points to place by the agency of spring pressure or torsion acting directly on the shaft or the crank. With the foregoing dangers in view, so far as springs on the head rod and spring connecting rods are concerned, it is the practice on some roads to have one of the thimbles on the connecting rod bear directly against the solid lug on the head rod, for the closed position of the switch, and the other thimble against the spring, for the open position, thereby maintaining a rigid connection when the switch is set for main line and providing a spring connection when the switch is set for the side-track. A standard arrangement of the Pennsylvania R. R. is a Lorenz spring connected with the switch and with a simple ground lever in this manner, as illustrated in Fig. 142A.

The action of the spring connecting rod (*J* and *K*, Fig. 145) is essentially the same as that of the Lorenz spring, the only difference being that the spring is placed in the connecting rod instead of on the head rod. The Burlington & Missouri River R. R. has in use in some of its yards a spring connecting rod in which the rod itself is shaped to form the spring. The design was suggested by Roadmaster Patrick O'Donnell, and it is locally known as the "P. O. D." spring. By reference to Fig. 150 it will be seen that about 12 ins. of the rod is formed by a 3x⅜ in. steel bar looped eight times and securely bolted into slotted shanks in the two end pieces of the rod. The convolutions are 6½ ins. long and 1 in. apart. The rod is used with a rigid stand, and in case the point rails are trailed in the wrong position the rod will stretch or be squeezed together, permitting the points to be set over and the wheels to pass through the switch without doing damage to the points, and then return the points to position after the wheels have passed.

Figure 143 shows a "spring split switch," used mostly on electric railways in such places as passing sidings or loops, being intended to automatically switch cars to one side when they pass the switch in the facing direction and permit them to trail out when passing in the opposite direction. A housed spring attached to one of the point rails serves to hold the opposite point rail firmly against the main rail, and in this way serves as a slack adjustment device. A similar arrangement can be had by drilling through the webs of both point and stock rails and using a bolt and spiral spring similar to the spring bolt on a spring-rail frog. If the head of the bolt be made to catch the point rail, the coiled spring may be made to bear against the rail on the outside of the track or it may be placed in a housing. It must be obvious that either arrangement serves its purpose for one side only and tends to produce the opposite effect with lost motion on the other side. For this reason the device is seldom, if ever, used on point rails which are intended to be thrown by a switch stand.

Automatic Switch Stands.—Switch stands arranged for the automatic operation of point switches may be divided into two classes: the "fly-back" and the "set-over." Stands of the former class return the switch to its original position after being forced aside by trailing wheels; with the "set-over" stands there is provided a connection with sufficient resistance to hold the points for proper service, but the points are moved through a complete throw upon being forced aside. This arrangement thus permits of an automatic change in the position of the switch. The foregoing spring switches and spring connecting rods have the so-called "fly-back" action. With devices of the fly-back variety the switch is retained in one position, as locked, despite an automatic or improper use of it. With the set-over or complete-throw automatic stand, the switch, if misused by careless employees by trailing out of a side-track when it is set for main line, may chance to remain open in the face of main-line trains. In this respect, therefore, it is inferior to the fly-back device. It is considered, however, that it serves as a telltale on careless employees, whereas the other device does not; and that in case a train should trail part of its length through a wrongly set switch provided with this stand, and then back up, the train would not be broken in two by straddling the tracks, as it unavoidably would be with a fly-back arrangement. In instances of such culpable negligence, however, the fly-back device would act as telltale and, for such occurrences alone, despite the consequences to the train, it would seem to be the more valuable device for the company. Some complete-throw automatic stands do also have in their favor the advantage that the points are not held in position by direct spring pressure or torsional action on the shaft. There is therefore no direct stress on the spring and consequently less liability that it will break in service.

The Long "safety" stand is of the fly-back type. It is used on the Bangor & Aroostook, Chicago & Alton, New York, New Haven & Hartford, the Southern and other roads. Briefly stated, the shaft of the stand is engaged with a stiff spiral spring made of 14ft. of steel bar and coiled around the shaft. The hand lever for revolving the shaft is not engaged directly therewith, except when it is raised to throw the switch; normally it is engaged with the spiral spring. The crank is rigidly connected with the point rails. The spring around the shaft takes up all play or lost motion, so that the connecting rod is held by the force exerted by the spring. This spring will allow the shaft to turn and the switch to be thrown automatically should a car or train trail through it when it is set the wrong



LONG SAFETY STAND — WEIR AUTOMATIC STAND

Fig. 151.—Automatic Switch Stands.

way. More in detail, the shaft or crank spindle *A* (Fig. 151) extends in one solid piece from target to crank, through the tubular handle shaft *B*, outside of which the spring *E* and its collars *C, D,* and *F* are carried. In hand operation the handle is positively engaged with the shaft *A*, by its knife-blade end, which enters a slot in the shaft as the handle is thrown up, and all these parts move as one; they are locked in place by folding the handle into a notch in the frame *H*. Any obstruction between point and stock rails will not allow the shaft to turn far enough to permit the handle to be folded into the notch, and hence is detected at once. A spur *Bb*, on the lower end of the handle shaft *B*, holds the spring from unwinding, causing the spur *Ca*, on the upper spring collar *C*, to press against the arm *Ac* which is fixed on the crank shaft *A*, thus applying the power of the spring against the shaft, the switch rod and the switch. An automatic movement of the switch will move the rod in the direction of the arrow, and the power thus applied will act to wind up and increase the stress on the spring, the reaction of which will promptly return the switch to position after the wheels pass off. For an automatic action in the reverse direction, the switch and crank being in the other position, the spur *Ba* holds against the upper end of the spring, the power of which is applied against the arm *Ab* on the shaft below the spring. The tension of the spring is increased, when required, by forcibly turning collar *D,* under the collar *C,* against the spring, by a bar inserted under the step, the door *Hb* being removable to obtain access to the spring.

The Weir automatic stand, shown also in Fig. 151, is of the complete-throw type. It is used on the Chicago & Northwestern, Chicago, Milwaukee & St. Paul, Central of Georgia and other roads. On the back side of the stand there is a V-shaped box cast as part of the stand, containing spring pockets *P,* top and bottom. On the back of this box there is a hood *H,* held to place by bolts engaging with springs in the pockets *P.* The springs are seated in the back sides of the pockets and hence their action on the bolts tends to draw the hood towards the front of the stand —that is, towards the shaft. Within the lever casting *C,* which is rigidly fastened to the shaft, there is a sliding bar *S* connected by means of a link to the hood *H.* The other end of the sliding bar is operated on by the handle by a cam-like action which crowds the bar towards the hood when the handle is folded downward, but permits it to slide from the hood when the handle is thrown up to the horizontal. There is thus no strain on the springs when the stand is thrown by hand. The lever is not locked in any definite position, but upon being folded down, when the switch is thrown to either side, the sliding bar *S* is crowded backward, compressing the springs, the reaction of which produces a turning effect on the shaft and forces the switch points tightly against the stock rail. The stock or through rail thus acts as a final stop to the action of the springs; and should lost motion result from wear of parts or widening of the gage, the throw of the crank is automatically adjusted to the changed conditions. The tension of the springs can be regulated by a set screw in the back of the hood, which does not appear in the figure. In the automatic action of the stand the shaft is turned against the pressure of the springs until the sliding bar and link (which form a toggle-joint) are moved over the center, when the action of the springs sets the points entirely over the other way.

One of the best known, as well as one of the most widely used, automatic switch stands is the Ramapo device (Snow's patent), Fig. 152. Of the two stands shown that at the right is provided with a crank of fixed length and that at the left with a crank of adjustable length. In other respects the stands are of identical construction and their manner of operation is the same. The crank and shaft are rigidly engaged with the handle, so that in hand operation there is positive action between handle and switch. There is a "safety block" *B,* ribbed to fit into the grooved "safety cap" *C.* When the handle is raised to throw the switch the safety block is lifted by link motion and the handle cannot be lowered and locked to the stand until the points are thrown entirely home, permitting the safety block to slide into the safety cap. Any obstruction between a switch point and the stock rail is, therefore, readily detected. The under side of the cap or head *C* forms one jaw of a clutch, and the block *E,* sliding in a guideway in the frame of the stand and backed by a spring, forms the other jaw. Obviously, this block is held against turning. If the switch is set the wrong way for trailing wheels, the shaft and cap, being locked together, turn as one, forcing down the lower jaw of the clutch (see right-hand view in the figure), which, as soon as the teeth pass, being actuated by the spring, sets the points over to the other position. The projecting stud S is a stop which serves to limit the throw of the crank. The stand is also made with the crank upturned to meet the bottom of the base casting, so that the connecting rod cannot be taken off without releasing the shaft from its fastenings. If desired, the stand can be made to work automatically one way only, so that the points, if wrongly set for a train trailing them on main track, will be automatically thrown without damage, but not for a train trailing out of the siding when the points are set for main track.

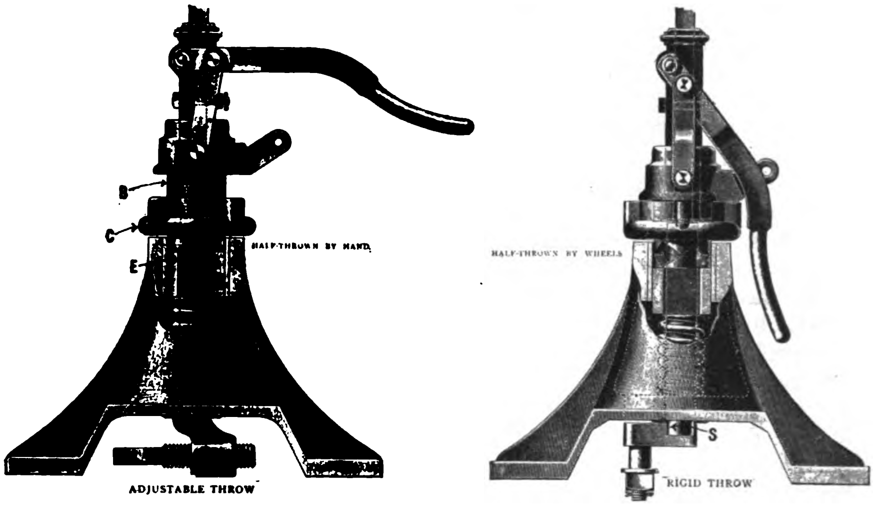


Fig. 152.—Ramapo Automatic Switch Stand.

The adjustable crank, above referred to, consists of a heavy eye bolt screwed into a stout shank at the bottom of the shaft. As this device permits a change to be made in the throw of the stand the advantage in the use of the same is readily seen. A switch stand with an adjustable crank will work with any switch with which it is desired that it shall be used, as the throw may be adjusted to correspond to that of the switch; whereas the crank of fixed length requires that the stand shall be specially made to fit the throw of the switch. Figure 153 shows an adjustable connecting rod intended for use with this stand. The rod has a screw jaw on one end, and this device, in connection with the adjustable crank, enables an adjustment of the points from one side to the other, so that in setting up the stand it may be firmly spiked to the headblock and the rod afterwards adjusted to the proper length to throw the switch to a close fit in either direction. The adjustable crank and the adjustable connecting rod thus obviate the necessity for adjustable head rods and adjustable points in split switches. The screw jaw on the connecting rod and the adjustable crank cannot be turned without disconnecting the two, so that the arrangement is not readily tampered with, and the parts cannot of themselves work loose and change the adjustment of the switch or stand.

The Axel stand (Fig 154) is similar in action to the Ramapo stand, and about the only difference in construction is in the position of the

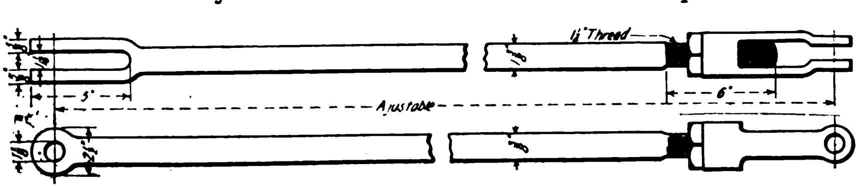


Fig. 153.—Adjustable Connecting Rod.

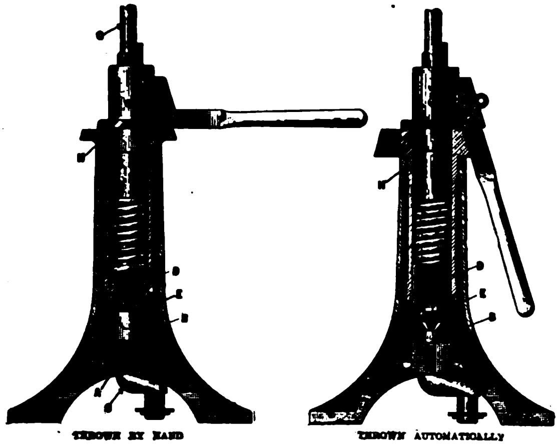


Fig. 154.—Axel Automatic Switch Stand.

clutch. The shaft C is one piece from crank to target. The spider A and the clutch jaw B are essentially one piece, the spider being cast with, or made fast to, the frame of the stand. The upper jaw E, of the clutch, forms one piece with the shank D, which is square in cross-section and held against turning by the head H. The handle is rigidly attached to the shaft and folds downward into a notch in the head H, so that the points must be closed home before the handle can be put to place. In the automatic action of the stand the head is turned, disengaging the clutch against the compression of the spring. This stand is used on the Burlington, Cedar Rapids & Northern and some other roads.

The Wharton automatic stand (Suffern and Kidd's patent), shown in Fig. 155, is similar to the Weir stand in action, but quite dissimilar in appearance and in detail of construction. The cast iron frame is made in two parts, A and A^1. The shaft B is of rolled steel and square in cross-section. The crank B^1 is at the extreme end of the shaft, as ordinarily, and

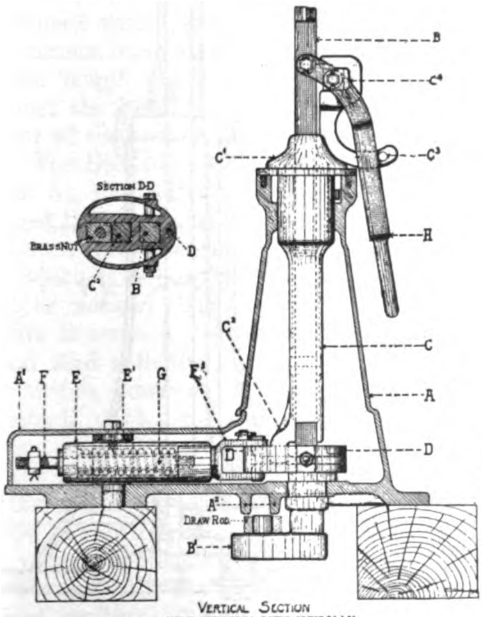


Fig. 155.—Wharton Automatic Switch Stand.

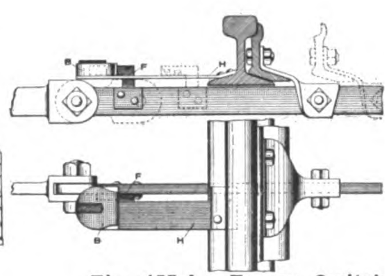


Fig. 155 A.—Emery Switch Point Lock.

a locking plunger C extends from top to bottom of the stand, turning with the shaft B and resting on the top of the frame by the collar C^1. At the lower end of the plunger C there is a locking finger C^2, which fits into a slot in the upper crank D when the lever is lowered. The extending arm C^3 C^4 is provided with a hole at C^3 to receive the lock, and with a slot at C^4, in which slides a brass nut pivoted to the hand lever H, by which means the plunger C is raised and lowered with the hand lever. Parts C, C^1, C^2, C^3 and C^4 are in one piece of malleable iron. The malleable iron Crank D, rigidly fastened to the main shaft, is provided with a slot to receive the locking finger and a brass nut pivoted to the jaw F^1. Part E is a cylinder serving for a spring casing and E^1 are trunnions upon which the spring casing swings. The rod F extends through cylinder E, one end being rigidly fastened to jaw F^1, to which the brass nut sliding in slotted crank D is pivoted. The spiral spring G is coiled around the rod F and confined between the end of jaw F^1 and the end of the spring casing. In the figure the stand is shown as it would appear when half thrown automatically. The locking finger C^2 is in the slot in crank D and prevents the brass nut pivoted to jaw F^1 from sliding inward toward the shaft. The spring is therefore compressed and the jaw F^1 and rod F are forced into the spring casing. As soon as the central position (dead center) is passed the spring expands and forces the shaft and handle around to the opposite position, thereby throwing the switch points over against the stock rail. In throwing the stand by hand the plunger and locking finger are raised, the brass nut pivoted to jaw F^1 slides inward in its slot in crank D and the spring is not compressed. Unlike the Weir stand, the spring is not compressed except during the automatic operation of the stand. The throw of the crank is adjusted by the nut on the rod F, the length of this rod limiting the turning of the crank D and hence the throw of the crank B^1. As the locking finger C^2 cannot be lowered into its slot until the points have been thrown their full distance, the handle of the stand cannot be lowered and locked if there is an obstruction to the movement of the points. In or-

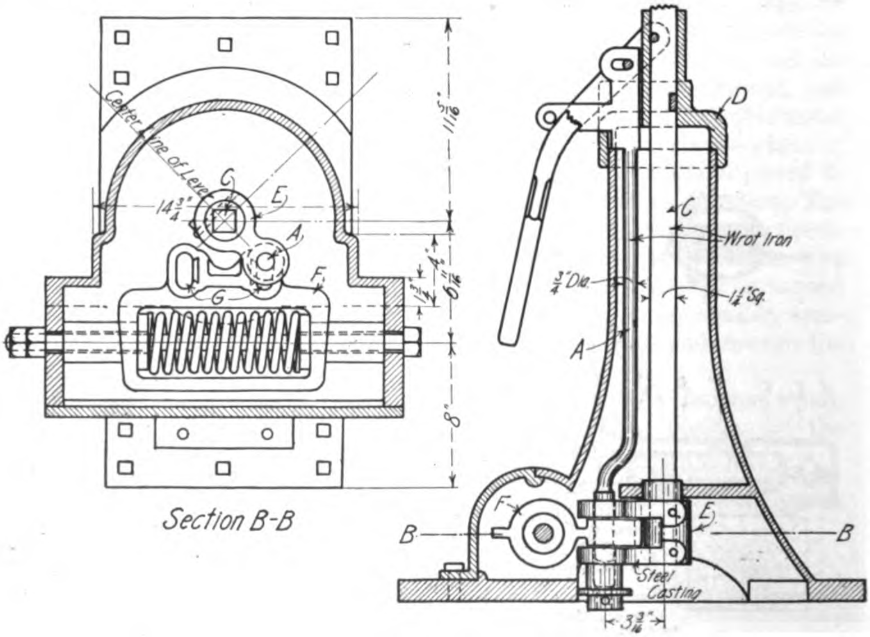


Fig. 156.—Standard Switch Stand, Southern Pacific Co.

der to engage or disengage the connecting rod it is necessary to remove lid A^1 and the spring casing and turn the shaft so that the crank passes beyond the embrace of the cast arc A^2. A stand with the same spring application is made in a yard pattern only about 10 ins. high, to top of the lever.

The standard switch stand of the Southern Pacific road is designed with a spring action to return the points to their original position in case they should be trailed through by a car or engine, when set in the wrong position, and by means of a locking device the switch-stand lever cannot be dropped into its normal position without first throwing the switch point fully up against the stock rail. This stand (Fig. 156), designed by Mr. J. H. Wallace, engineer maintenance of way of the company, consists of the ordinary vertical cast iron shell, with a rotary head or cap (*D*) fitted over the top of the shell and rigidly attached to a crank shaft (*C*) of square cross section. The crank (*E*) which throws the switch is a steel casting slotted to straddle the horizontal projection of a cast steel locking frame (*F*) which encloses a spiral spring on a bolt passing through the spring box, at the foot of the stand. This spring exerts its tension against the collared ends of sleeves passing through disks which form two sides of the frame. Thus the locking frame, by compressing the spring, is capable of movement in either direction. This frame has slotted openings (*G*) which register with a circular opening in the end of the crank when the switch stand is set in either the open or closed position. Attached to the switch-stand lever there is a vertical rod (*A*) formed into a pin at the lower end, which fits into the opening at the end of the crank and into the slot in the locking frame. This rod is connected with the lever at such a distance from the fulcrum of the latter that when the lever is raised from its normal position it withdraws the pin from the slot, permitting the stand to be thrown without engaging the spring mechanism. The lever cannot then be dropped to its normal position until the switch points have been thrown fully home, permitting the locking rod to enter the crank opening and the slot in the locking frame. When this connection is made the crank, the main shaft (*C*) and the revolving head (*D*) are locked into an engagement with the spring, and any ordinary force applied to the switch rail cannot move it from its position. A car or train trailing through the switch points placed in the wrong position will, however, set them over against the tension of the spring, and after the wheels have passed, the power of the spring will move the switch back to its original position.

The Steelton switch stand, the standard of the Nashville, Chattanooga & St. Louis Ry., is designed for use with a Lorenz spring and so arranged that the lever cannot be latched to lock the stand unless the switch has been thrown entirely home. The spring is in full use for all purposes for which it is intended, and works both ways. Referring to Fig. 157, it will be noticed that the stand has a spring connection with the switch points through a Lorenz spring, in the same manner as with any plain stand used with this spring. When the handle or lever is raised to throw the switch, however, the shaft is put in rigid connection with the switch points, through a rod connecting rigidly with the head tie bar of the points at one end and curved over at its other end so as to lie between jaws keyed to the shaft. Projecting through these jaws is the lock rod *F*, attached to the end of the lever or handle *D*, at *C*. When the handle *D* is raised to throw the switch the rod *F* is shoved downward through a hole in the curved rod connecting with the head rod, thereby placing the stand in rigid connection with the switch points so long as the lever *D* remains in the raised position. As this lever cannot be dropped until it is thrown far enough around to meet the notch in the table of the stand, it is clear that

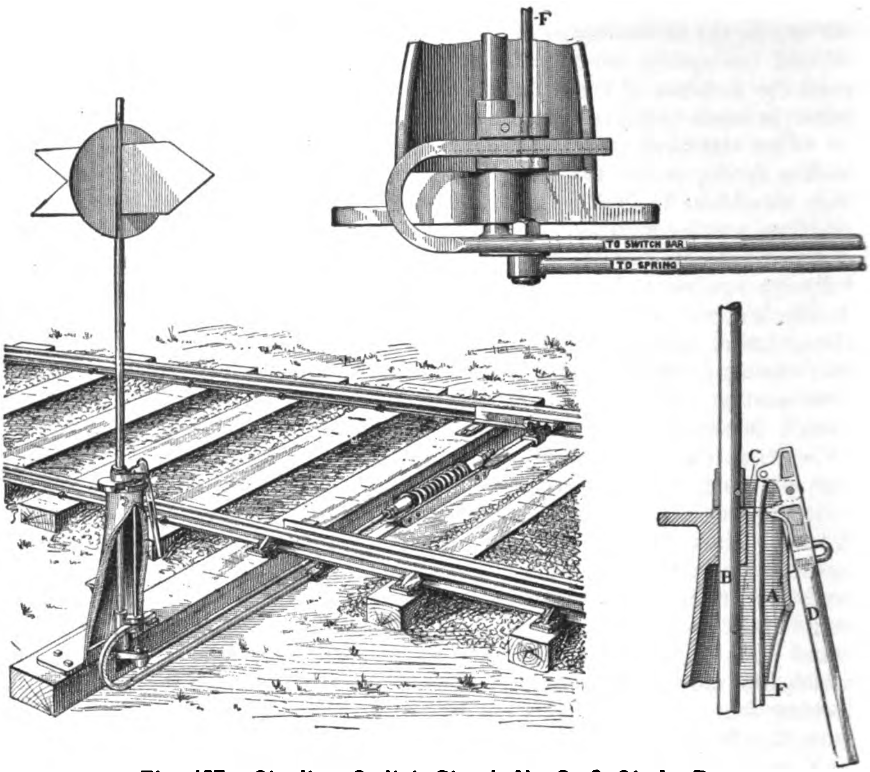


Fig. 157.—Steelton Switch Stand, N., C. & St. L. Ry.

the rigid connection to the switch cannot be broken until the points are thrown fully up to the stock rail. As soon as they have been thrown thus far, however, the lever is folded into the notch, the lock rod *F* is drawn upward, the rigid connection is broken and the stand remains spring-connected to the switch points through the Lorenz spring; so that in whatever position the stand is set or locked a train trailing the points set the wrong way will throw them automatically against the spring connection. An important advantage which the N., C. & St. L. people have found with this type of stand is that spreading of the gage at the stock rails or loosening of the stand is promptly made known by the refusal of the stand to work. If the lock bar *F* fails to fit into the hole in the head rod connection it is impossible to operate the stand, as the lever cannot be raised out of its notch. Hence a loose condition of things at the switch cannot exist very long, even if it should occur, for in order that the stand may be used the section foremen are required to keep the track at the switch to the proper gage and the stand securely fastened. The automatic switch stand of the Burlington & Missouri River R. R. (Fig. 134B) is described in connection with lever-lock switch stands.

There is reasonable distrust in the general use of automatic switch stands or other automatic switch devices. In the first place, it is not to be denied that the use of automatic switches and automatic stands, by switching crews, begets carelessness. For this reason many think it is not worth while to provide automatic devices with the sole object of permitting trains to trail from side-tracks through wrongly set switches without damaging the switch or being derailed. As such trains usually move at slow speed no great damage can result from derailment, and it would undoubtedly conduce to better discipline if the results of the negligent use of the switch were visibly indicated by injured point rails or by derailment, in case the switch is provided with a point lock. It is highly desirable, however, that a switch should operate automatically when wrongly set and trailed by a main-line train, since in forcing the points over against rigid connections there is some risk of derailment, and in any case the injury to the points or their rigid connections leaves the switch in dangerous condition for facing trains. On double track, therefore, it would seem desirable that trailing switches should work automatically, at least one way; that is, when wrongly set for main-track trains. For single track greatest safety can be had only by the use of a switch point lock for the main-track position of the switch. This arrangement renders unserviceable any automatic device for trains trailing out of the side-track when the switch is set for main track; but it is no hindrance to the automatic throwing of the switch when wrongly set for trains trailing through it on main track. Hence there is some utility in using a Lorenz spring, spring connecting rod or automatic stand with a switch point lock. Next best to this arrangement is a Lorenz spring or automatic stand rigidly connected for the main-track position; that is, adjustable only for the side-track position. For double-track trailing switches some form of automatic stand which has positive or rigid engagement of the hand lever with the point rails in hand operation is undoubtedly preferable. This form of automatic stand is preferable to the automatic switch spring connected both ways, because it does not permit of being locked until the point has been thrown entirely home against the stock rail.

The argument against the use of a spring connection or automatic arrangement for the main-track position of the switch, on single track, is not entirely one sided, for if an engine is run out of a side-track through a rigidly-connected switch set in the wrong position the injury to the points or the connections may leave the switch in dangerous condition for facing trains; and the fear is that an engine crew might do this and depart without stopping to examine the condition of the switch; in fact such cases are on record. But in the use of the automatic stand or a spring connection for facing-point switches there is (whether justly founded or not) widespread distrust in the integrity of any clutch or spring device to hold the points firmly to their place. Should the spring break or become weakened through service, it is thought, and actually asserted as having occurred, that the points after having been automatically thrown may chance to remain partly open, which, under some circumstances, would be the most dangerous position possible; it is also possible for the same condition to result from excessive wear of clutches. At any rate the use of automatic stands for facing-point switches is considered among trackmen a debatable question. For facing-point switches on double track a switch-point lock is undoubtedly a desirable arrangement, whether an automatic stand or spring connection is used with it or not.

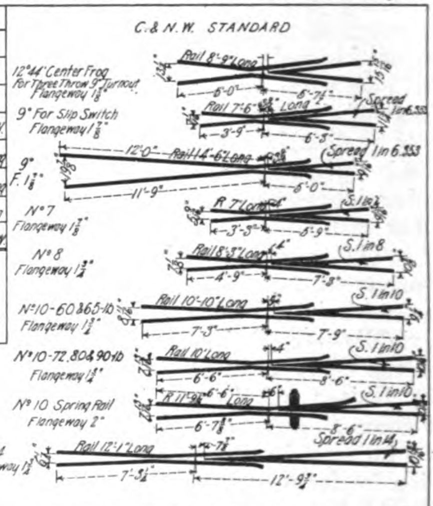
Where a car or train has trailed through a non-automatic or rigidly-connected point switch set the wrong way, the switch should be looked after immediately, because the points, or the connection with them, will usually be found loosened to an extent which leaves the switch in a dangerous condition for facing trains. The tie rod clips should be closely examined to see whether they are bent, as if they are they will permit the point rails to cant out of their proper position against the stock rails. The switch stand also should be carefully inspected, and particularly with reference to the crank of the main shaft, as any bending of the same out of its proper shape necessarily changes the throw of the stand. The connecting rod should also be carefully inspected with reference to any bending from the original shape. The bending of a straight rod shortens the distance between its end connections, and the straightening of a rod crooked at some part (as connecting rods frequently are) lengthens the distance between its end connections, in either of which cases the throw of the switch may be considerably changed. The extent of such damage may, of course, be ascertained by throwing the switch.

On some roads automatic switches or stands are used in yards but not on main track. Such practice is explained by a fear concerning the entire reliability of such devices in high-speed tracks, but with a view to avoid damage to switch points where a great deal of switching is being done at slow speed, and where trainmen are frequently more or less careless. It is no uncommon occurrence for trainmen working on yard tracks to trail a train against rigidly connected point switches wrongly set. Of course such is bad discipline, but these matters are not under the control of the track department, and for this reason some roadmasters find that they can avoid a good deal of trouble by using spring devices with their split

Designation	Angle	Curve Degree	Curve Radius	P.C. to P.F.	H.B. to P.F.
1 in 5	11°25'16"	24°31'36"	235.4'	47.08'	
1 in 6	9°31'39"	16°57'52"	338.97'	56.5'	
9° Special	(For Double Slip)				
9° (1 in 6.353)	9°00'	15°07'	380.05'	59.85'	56.75' 1-30' Rail, 15' Point, 11 25/ W.
1 in 7	8°10'16"	12°27'	461.1'	65.92'	61.14' 1-28' 1-14.89' Rails, 15' Point, 3 25/ Wing
1 in 8	7°09'10"	9°30'	603.8'	75.33'	67.75' 2-24' Rails, 15' Point, 4 25/ Wing
1 in 10	5°43'30"	6°05'	942.3'	94.16'	81.5 2-30' Rails, 15' Point, 6 5/ Wing
1 in 14	4°05'26"	3°06'	1848.5'	131.8'	117.27 3-30' Rails, 20' Point, 7-3 1/4" W.

Rail	Hight	Head	Base
60-lb	4 1/4"	2 5/16"	4 3/16"
65 "	4 3/8"	2 3/16" 2 21/32"	4 5/16"
72 "	4 3/4"	2 3/8"	4 3/4"
80 "	5"	2 1/2"	5"
90 "	5 3/8"	2 9/16"	5 3/8"

No. 10 72-lb same as No. 10 80-lb excepting 6" bet. Theoretical & Actual Points.
9° 60-lb (17' Frog) same as 9° 72-lb
Present Width of Flangeways Adopted 1895



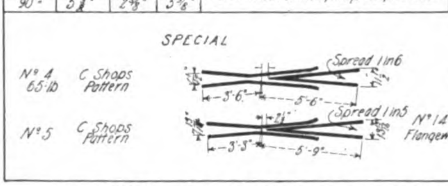


Fig. 157 A.—Standard Frog and Turnout Measurements, C. & N. W. Ry.

switches in yards. As an instance, I have official information of a Ramapo switch stand used in a yard on a switch that is trailed in the wrong position habitually. The engines or cars throw the points automatically, and the switch has been used in this manner for more than five years, without any trouble.

69. Laying Point-Switch Turnouts.—For laying point switches originally—that is, when they are not being laid to replace stub switches—a little calculation will enable one to fix upon a standard frog angle or length of frog which will give the proper lead without cutting any rail. In this respect the point switch has many advantages over the stub switch, since there are no joints to calculate upon meeting exactly. The only difficulty to be guarded against is that of meeting a joint the inside splice bar of which might interfere with the throwing of the point rails, or possibly of having a joint come too near the bend in the stock rail. Usually, a frog numbered somewhere between 9 and 10—depending upon the length of the frog, the length of the points and the spread at the heel—will require a lead such that, in either square or broken-jointed track, by taking out three 30-ft. rails on the frog side, the frog, two 30-ft. rails and the points may be connected and put down to bring no joint to interfere with the point rails or the bent rail. More attention is being given to the matter of avoiding the cutting of rails than was formerly the case. On the Chicago & Northwestern Ry. the angles of the frogs or the lengths of the same are so calculated that closure rails of convenient length will fit into the leads without cutting—in ordinary cases 30-ft. rails are used. The data of these frogs and the lead measurements are contained in Fig. 157A. It will be noticed that no two frogs of different number are of the same length. Sometimes by using a fish plate inside at the joint, instead of an angle bar, or by cutting off the lower leg of the angle bar, a joint otherwise too close becomes not bothersome. To trim off the horizontal part of an angle bar, notch the bar along the angle with a track chisel, as in preparing to cut a rail, lay the angle bar over a rail, angle up, and strike the vertex with a sledge hammer. Whenever it is feasible to do so it is well to have the point rails break joints with the through rail and stock rail. The roadmaster who starts out laying his turnouts to some standard, will save himself much trouble in later years.

The rails on the side opposite the frog need not be disturbed at all. After the location of the frog has been determined upon and the switch ties have been put in, the guard rail in main track opposite the frog may be laid. Next, the frog, point rails already connected, the intervening lead rails and the bent or stock rail must all go in at the same time. By taking measurement the bent rail can be made ready beforehand. A sure and accurate way of taking these measurements is to place the frog, the point rails and the intervening rails end to end at the side of the main rails, in the order they are to come when the turnout is completed, and mark the desired points on the track rails with a chisel. The bend in the stock rail is best made sharply, with a jim-crow, and it should correspond to the angle of the point rails. This completes the order of the main-track part of the work. The turnout rails may be laid when it comes most convenient. Until the stand is connected no train should be allowed to pass the points without first spiking them to place, and to make secure for trains that come facing they should be braced temporarily with angle bars or blocks of wood spiked to the ties. The headblock may be put in either before or after the point rails, but it is usually placed along with the switch ties. Regarding the remainder of the work the same rules and practice apply as when laying a stub-switch turnout.

70. Changing Stub Switch to Point Switch.—Before doing anything at all toward substituting a point switch for a stub switch it should first be ascertained whether the old switch stand is going to throw right for the point rails; if not, a stand of proper throw should be provided. Up to and including a No. 10 frog, the toe of the stub switch may be used for the heel of the point switch with the same frog, by changing slightly the curvature of the turnout rails. All that need be done, then, besides altering the curvature, is to change the headblock to its proper place under the point rails and to connect the point rails to the old stub lead rails. The point rail on the frog side is spliced to the main-track lead rail and the other point rail to the turnout lead rail. The old moving rail on the side opposite the frog is spliced at the old toe joint, forming the through rail, while the other moving rail is made the bent rail, or is replaced by a bent rail, which is then spliced to the turnout rail. The ties which were used under the old moving rails may have to be adzed in order to let the slide plates under the point rails, or they may have to be rearranged to suit the switch rods, or new ones be placed in their stead.

71. Three-Throw Switches.—A "three-way" or "three-throw" switch is one which can be thrown for three tracks. The combination where such a switch is used is sometimes called a double turnout. It affords convenience in switching, besides a saving in space, labor and material. There are two kinds: one having turnouts to opposite sides of the main track and the other having both turnouts to the same side of main track. Where the main track is straight and the turnouts lead to opposite sides they are usually made the same degree of curve, and consequently frogs of the same number are used in both, in order that they may be placed directly opposite each other. The inside wing rail of each frog then acts as guard rail for the other frog. Where two frogs would come near each other in opposite sides of the same track it is always desirable to place them directly opposite, rather than nearly so, because if they are not opposite, a guard rail must be provided for each, which, for lack of room, must necessarily be short and insecure. The guard rail opposite the frog which is farther from the headblock may, by using a special filler block, be bolted on to form an extension of the inside wing rail of the other frog, and be made secure; but a guard rail for the frog nearest the headblock would in that case come within or near the mouth of the opposite frog, where it would be either impracticable or especially undesirable. In all respects regarding distances both turnouts are the same as a single turnout having a frog of the given number; the length of switch rail is the same and the lead distance is the same.

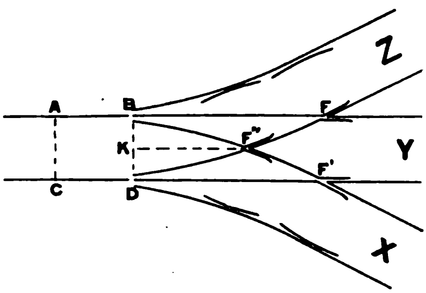


Fig. 158.

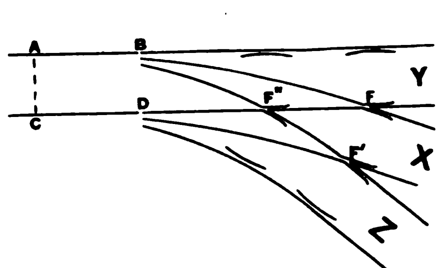


Fig. 159.

Where the two outside rails of both turnouts cross each other a third frog (F'', Fig. 158) is needed. It is called the "middle" or "crotch" frog, and its legs should be curved to fit the two turnouts. Its number is always approximately .707 times the number of the main-track frog. Its point is located in the middle of the track a distance ($K\ F''$) from the toe of the (stub) switch which is found by multiplying the gage by 1.414 times the main-track frog number, and subtracting from this product (1.414 gn) the length of switch rail for the same frog number. It is thus seen that the distance from heel of switch to point of crotch frog is 7 tenths of the total lead, and the distance from crotch frog to main frog is 3 tenths of the total lead, or 2.82 × frog number. The crotch frog may therefore be spiked to place at any time, by measurement, and the lead rails can be cut to fit in with it afterward. Where no frog of a number equal to .707 times the number of F or F' can be had, a frog of nearly that number may be used and the turnout curve made compound, the point of the crotch frog being made the P. C. C. Any frog having an angle not greater than twice the angle of the main-track frog will answer, but the lead distances to both the middle and main-track frogs will in that case not be the same as with a proper middle frog; the problem becomes more complicated and the formulas for simple-curve turnouts cannot be applied. In the practice of some roads the standard angle or number for yard frogs is such that these frogs may be used as crotch frogs for the standard frogs for main track; as, for instance, No. 7 and No. 10 frogs and No. 6½ and No. 9 frogs go well together for this purpose. On the Atchison, Topeka & Santa Fe Ry. three sizes of frogs are standard; namely, No. 9, No. $6\frac{1}{2}$ and No. $4\frac{1}{2}$. No. $6\frac{1}{2}$ is the crotch frog for main-line double turnouts, where the main frogs are No. 9. Where No. $6\frac{1}{2}$ frogs are used in double turnouts the crotch frog is No. $4\frac{1}{2}$.

Where both turnouts lead from the same side of straight track the frogs (F, F' and F'', Fig. 159) remain the same as with turnouts leading from opposite sides: F' should equal F in angle and be placed directly opposite to it. It is very undesirable to have it unlike F, as in that event it could not be placed opposite to it, the objection to which practice has already been stated. The number of F'', the crotch frog, remains .707 times the number of the main frog F or F' and, instead of being found in the middle of the main track, as before, it is now on the frog rail of the main track. The turnout Z may then be considered without reference to turnout X, the same as any ordinary turnout from the main track, having a frog angle F'' and a throw twice the ordinary. The length of switch rail for Z may be found by the ordinary formula and is almost identical with the switch rail for X; for, while the radius for Z is practically only half ($\frac{1}{2}\ R - \frac{1}{4}\ g$) that for X, the throw is twice that for X and the switch rails for the two turnouts are practically equal in length. The greatest objection to a three-throw switch of this kind is that while the switch rail for the second turnout is required to be no longer than for the first, it must be thrown a distance great in proportion to its length. The lead distance ($D\ F''$) of the crotch frog F'', from the headblock, is found by the same formula that would be used for any turnout; viz., 2 gn'' minus length of switch rail. By substitution, 2 gn'' will be found equal to 1.414 gn, as given above. The location of the point of F'' may be found also by trial. Put in the two main frogs and line the lead rails to them. The point F'' is found on the main track gage line at such a point that the distance between the far rail of the main track and the far rail of the turnout is twice the track gage. In measuring, the tape line must, of course, be held squarely across both tracks at the same time; which means that it must change direction at the middle. All such fussing, however, gives more trouble than to find the location by computing and measuring off the proper distance from the headblock.

The consideration of X and Z as turnouts from the same side is only conventional, for if we consider X the main track we may consider Y and Z as turnouts from the opposite sides of a curve, they really being such. The frog F being of such number as will require from straight track a turnout of curvature equal to that of the main curve, as heretofore explained for turnouts from curves, the turnout Y, being *against* the curve, has its curvature decreased by the main curvature and becomes straight track; while the turnout Z, having a frog of the same number and turning *with* the curve, has its curvature increased by the main curvature, or doubled. So the problem of turnouts from opposite sides of a curve is identical with that of turnouts from opposite sides of straight track, at least so far as regards the relation between middle and main frog numbers and lead distances.

In case the number of F'' is not .707 times the number of F, and the curve for turnout Z is compounded at F'', the lead distance for F'' and the curvature as far as F'' would be found in the same way as for a single turnout. The determination of the curvature from F'' to F', as well as the location of F', depends upon the angle of F'' and leads to problems too lengthy and too complicated to be taken up here. An expert trackman could, after lining the lead rails BF and BF'', locate the frog F' very well by trial by keeping its point at proper gage distance from rail *BF* and swinging it with reference to *F″* until the relative position of the two would seem to admit of a suitable curve. But such problems rarely occur and ordinarily their solution should be left to the engineer.

By going a little farther and providing a double set of moving rails, a third turnout (*W*, Fig. 160), turning either to the right or to the left, may be put in facing the other way, the rails *EF* and *GH* serving as its moving rails and all being thrown by one switch stand. The moving rails *EF* and *GH* may have their own switch rods independently of the rods for *AB* and *CD*, ordinary rods being used. In order to throw both sets of moving rails together they may be fitted, on one side, near the headblock, with a filler block of wood or iron and bolted together; or a double head rod, like the one shown in the figure, may serve both sets of moving rails. The two sets combined are not so stiff that they cannot be thrown by an

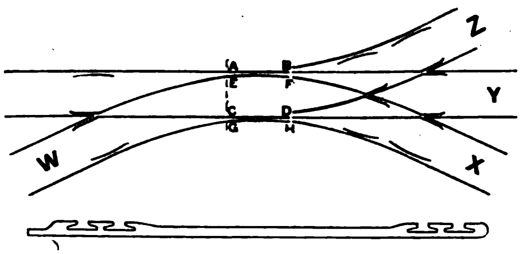


Fig. 160.—Double-Ended Turnout.

ordinary switch stand; but to add another pair to serve an additional turnout opposite to *W*, facing the same way, would probably make a switch too hard to throw in the ordinary manner. A three-throw stand will not throw the rails *EF* and *GH* to the track *Z*. Ordinary three-throw headshoes with the lugs knocked off answer for this switch. In case turnout *Z* was omitted the same arrangement of moving rails would still serve the tracks *W*, *X* and *Y*; that is, two turnouts from the same side facing in opposite directions; or if *X* was omitted there would be two turnouts facing in opposite directions and turning from opposite sides. The figure thus serves to show in how many different ways two sets of moving rails may be made to do service, as where space is wanting or where convenience may be gained, and by using nothing more than ordinary stub switch material. The ends *F* and *H* of the moving rails when thrown for turnout *W* are at the point of curve. In order to save room a switch like the one shown in Fig. 160 was laid by the writer several years ago, and was successfully operated, being in main track, at the entrance to a yard, where it was used many times each day.

Three-Throw Point Switches.—There are various arrangements for operating three-throw point switches. Figure 161 shows one operated by two stands on the same headblock. There are two sets of point rails, *CY*

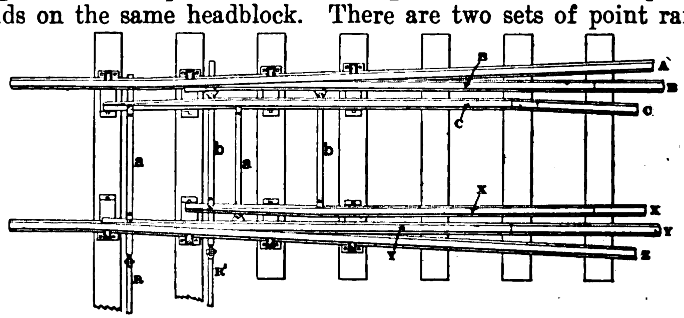


Fig. 161.—Three-Throw Point Switch.

and BX, each held together by rods independently of the other. The rods for the set BX are marked b, b, etc., and those for CY, a, a, etc. The set CY is operated by the rod R, and the set BX by the rod R'. The stock rails A and Z are both bent, when the turnouts lead to opposite sides; but when they lead to the same side only one of them is bent. By sighting along the plane of the paper, either facing or trailing the switch, the illustrations will appear much clearer to the reader. The switch is now set for the main track BY. By pushing on the rod R, the points CY only will be moved, placing C against B and setting the points for the turnout CZ. To set the switch for the track AX the points BX are pulled over by the rod R', so that point X is against Y when Y is set for main track. It will be seen, then, that before either set of points can be thrown for its turnout, the other set must be placed in the position which it would have for the main or middle track; and that when set for main track, use is made of one point rail of each set. The action is like that of the three-throw stub switch, in that, while throwing from one outside track to the other outside track, the switch must first be thrown to or by the position for the middle track—except that in this case it must be done with two stands instead of one. Both rods R and R' may be operated from the same side, or each may be operated by its own stand placed on either side of the track. It avoids confusion, however, and it is considered better in many ways, to have two headblocks, with the switch points widely removed from each

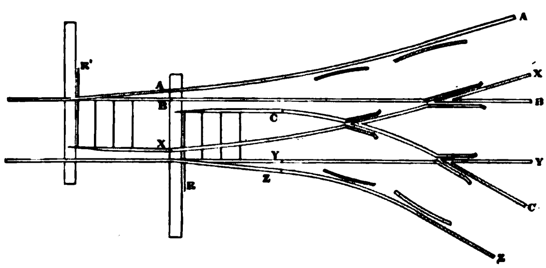


Fig. 162.—Tandem Point Switches.

other, arranged in tandem, as shown in outline in Fig. 162. The point of switch for track CZ is just in rear of the heel of the points BX, so that the ends of the points CY nicely clear the splices. In order that the frogs in the main or middle track may be placed opposite each other their angles must be such that their proper lead distances shall vary by the distance heel to heel of switch points. This scheme, like the other, is a combination of single turnouts, the arrangement serving the purpose of a three-throw switch only as regards saving of room and material. The switch points cannot be made to interfere with each other, as in the case of two stands operating on the same headblock. Should it be desired to use the turnout AX, it matters not what is the position of the points for the turnout CZ, but in order to use the turnout CZ, the switch for turnout AX must first be set in the normal position. In tandem split switches the front set of points is sometimes 15 ft. in length, with a rear set 10 ft. long. As with stub switches, so with split switches, both turnouts may lead to the same side of main track, the crotch frog then coming on the main rail, as in Fig. 159.

The true three-throw point switch is that where both sets of points are operated by one stand, those previously mentioned being really two switches separately operated. The Weir three-throw switch stand and the way it is connected to the switch points is shown in Fig. 163. The connecting rods have projecting pins which follow in a groove cut in a cylindrical shell or barrel turned by the hand lever. The groove is so arranged on the cylinder that, as the lever is thrown either way from the central or upright position, one rod is held still while the other is moved, and vice versa. The lever has a spring locking bar which fits into notches on the semi-circular locking plate, the same being part of the housing of the stand. The Hasty three-throw switch stand is shown in Figs. 164 and 165. The levers which throw the two connecting rods are operated by a cam arrangement which, through a certain range of the motion of the lever, can throw one of the rods without moving the other; while through the remainder of its range of motion, it throws the other without moving the first. Spring connection may be had with three-throw point switches the same as with ordinary switch points. If a switch rod or bridle plate is not used to hold the stock rails to gage at the point of switch the stock rails should be well braced on several ties, to take the pull of the two connecting rods. In order to facilitate the adjustment of the point rails some switch manufacturers are now making three-throw point switches with all tie rods adjustable.

In these point-switch double turnouts the lead distance for main-track frogs, and other measurements, are those heretofore given for point switches, according to the number of the frog used, the same as in single turnouts. The number of the middle or crotch frog, where the two points are thrown on one headblock, is always greater than .707 times the main-track frog number, and is given in Tables XIII and XIV. The angle of this middle frog (F'') is found by the formula

$$\cos \tfrac{1}{2}F'' = \cos F + \frac{\tfrac{1}{2}g}{R + \tfrac{1}{2}g},$$

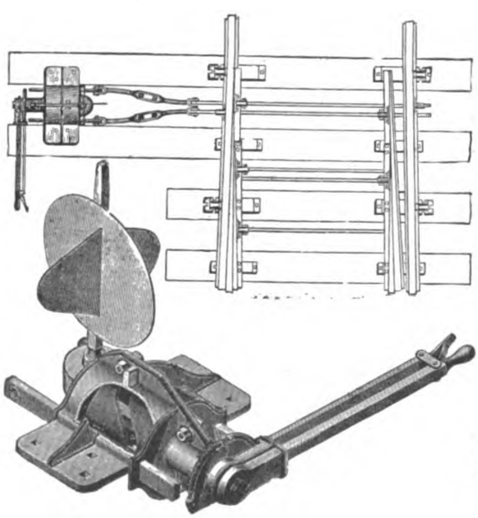
where R is the radius of the center line of the turnout curve. The number corresponding to the angle is found by the well-known formula

$$n'' = \tfrac{1}{2} \cot \tfrac{1}{2}F''$$

The lead distance from headblock to point of middle frog is not the same as it is with three-throw stub switches, but is equal to

$$p + (\tfrac{1}{2}g - h) \cot \tfrac{1}{2} (\tfrac{1}{2}F'' + P),$$

where g is the gage of the track; h, the spread at the heel; F'', the middle frog angle; P, the switch angle; and p, the length of the switch point.



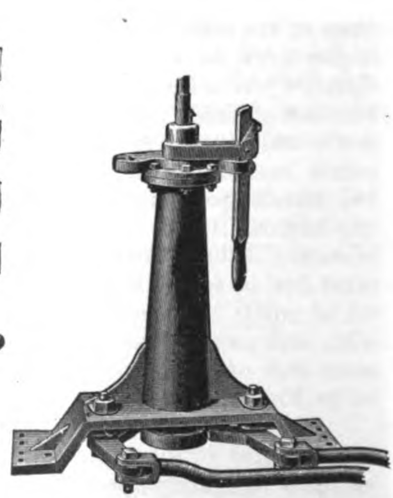


Fig. 163.—Weir 3-Throw Point Switch and Stand. Fig. 164.—Hasty Triple Stand.

Fig. 165.—Three-Throw Split Switch with Hasty Stand.

Where two points are thrown from different headblocks, as in Fig. 162, the angle of the middle frog and its position can be computed by coordinate geometry. Obviously it will not be placed in the middle of the main track, but a few inches from the middle and toward that side of the track which has the frog of lesser angle. The most rapid and most satisfactory method of determining the location of these points and the crotch frog angle is to lay out the turnouts on the draughting board to as large scale as is convenient. Measurements scaled off such a drawing will be accurate enough. Lengths of switch ties also can most conveniently be had from this drawing, and also the position of the mark on each tie which corresponds to the center of the main track. Mr. A. Torrey's book, "Switch Layouts," gives data for a large number of pieces of special work of this kind and affords a convenient and valuable reference.

Three Tracks on Four Rails.—There is a special arrangement of tracks used to some extent on ore and coal docks which requires a three-throw switch. In order to spot cars to best advantage for dumping into the pockets, four rails are laid over the dock about 4 ft. 11 ins. apart c. to c. or 4 ft. 8½ ins. apart in the clear, between heads, as shown in Fig. 166. The four rails thus stand to gage for three tracks, and the arrangement for shifting cars from the middle track to the track at either side, or vice versa, consists of a special double turnout with a three-throw switch and small-angle frogs in the middle track. The turnout shown, which is in service on the Duluth & Iron Range R. R., has two No. 25 spring-rail frogs and a No. 4½ crotch frog. The right and left leads from the three-throw switch turn out by 14-deg. curves, which are reversed at the heel of the crotch frog, into 15½-deg. curves as far as the heel of the spring frog in the main or middle track. The frogs (Fig. 167) have been styled "single-pointed," which term has reference to the construction of the point piece of the frog, by planing a single piece of rail to a point instead of joining two pieces of rail together, as in ordinary practice.

72. The Lap Switch.—Figure 169 shows the Elliot lap switch. In a general way it differs from the stub switch only in having the ends of the moving and stub rails beveled so as to lap a few inches by each other on the headshoe. For strength, the ends of the stub rails are flared and the web is retained on the beveled portion, the bevel being formed by planing off one side of the head and base. The ends of the fixed rails are bolted together through filling blocks which restrict the creeping of the moving rails to a safe limit. The switch was designed to overcome one of the objections raised to the stub switch due to the running of the rails from expansion, contraction or creeping of the steel. The switch rails are sometimes rendered immovable from running tight together, and sometimes the joint is too wide from contraction in a cold day. The lap switch provides a continuous-bearing rail regardless of a moderate amount of running, and saves a good deal of work at tamping headblocks, especially in yard tracks that are not well ballasted. In yards, where the tracks are much cut up by switches and excessive contraction cannot occur it would be well to use

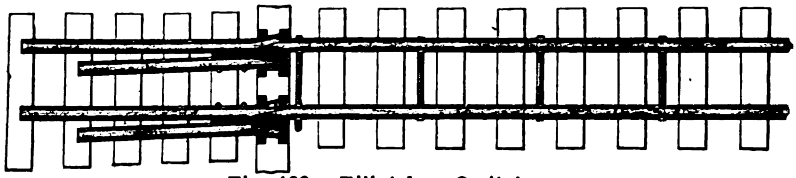


Fig. 169.—Elliot Lap Switch.

a spring connecting rod with this switch, to keep the beveled ends of the rails in contact and prevent strain on the connecting rod when the rails expand.

73. The Wharton Switch.—The only switch wherein both main-track rails remain unbroken is the Wharton or "lifting" switch. Except when thrown for the siding it stands entirely clear of main track. In Fig. 170, which shows diagrammatically the old form of Wharton switch, *A* and *B* represent two moving rails connected together like the split rails of a point switch, the rods connecting them being bent to pass under the main-track rail *H*. The rail *B* was formerly a grooved rail, but is now usually made a split or point rail. The outside switch rail *A* is an ordinary T-rail bent in a vertical plane. Both switch rails rest on a series of graduated iron blocks, called "elevation castings," which rise gradually from the point of switch so that about 3½ ft. therefrom they are 1¾ or 2 ins. higher than the main rails. In passing through the switch the wheels are thus lifted so that their flanges clear the rail *H* in passing across it. The elevation castings are continued behind the heel of the switch to gradually slope the turnout rails down to a direct bearing on the ties. In one form of this switch the shaft *D*, which operates the rails *B* and *A*, extends back and operates also the automatic trip rail *C*. This device is an ordinary guard rail with one end pivoted to an iron chair at *K*, while the other end is moved in against the main rail *H* when the switch is thrown for the turnout. By this arrangement the switch, if wrongly set for a train trailing it on main track, is thrown automatically by the crowding of the wheel flanges against the guard rail which, through its connection with the shaft

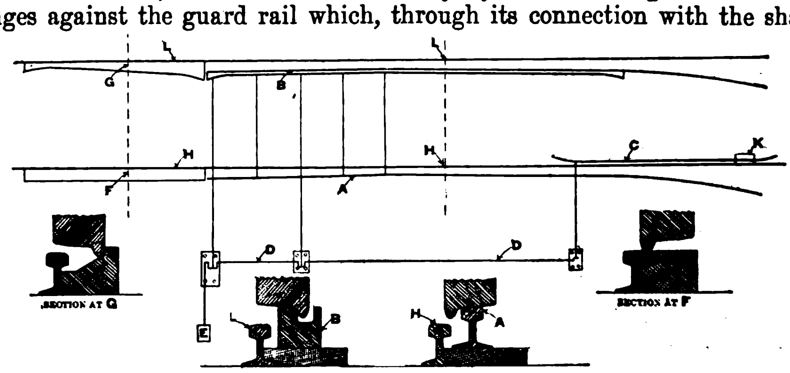


Fig. 170.—Diagram of Old Wharton Switch.

D, throws the moving rails. In yards the shaft need only be held by a weighted lever *E.* For a main track switch the lever, if set wrongly for main track, would not in all probability be locked; in case it was, however, a train trailing through the switch would break or bend the elevated rail *A* or its connection to *D,* but would not be derailed. In case the switch (old style) was wrongly set for a train coming out of the turnout the wheels, after leaving the switch rails, were caught by the safety guard rails *F* and *G* and so guided that they dropped to place on the main rails. Sections of these guard rails are shown in the figure. The guard *F* is the same hight as the main track rail throughout its whole length, except for a few inches near the end next to switch rail *A,* where it is sloped down about 1¼ ins. The inner side of *G* has a rib which, as it leaves the rail *B,* gradually approaches nearer the main-track rail *L.* This rib and the

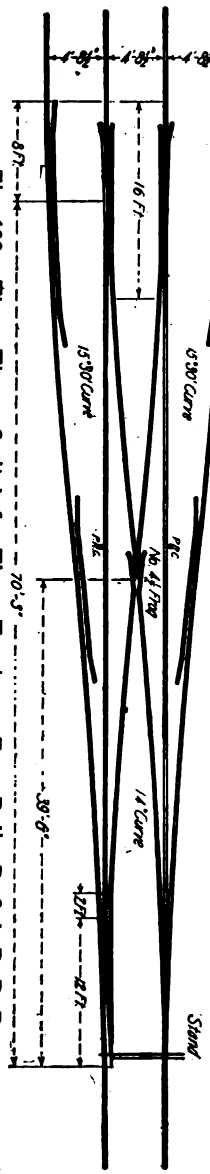


Fig. 166.—Three-Throw Switch for Three Tracks on Four Rails, D. & I. R. R. R.

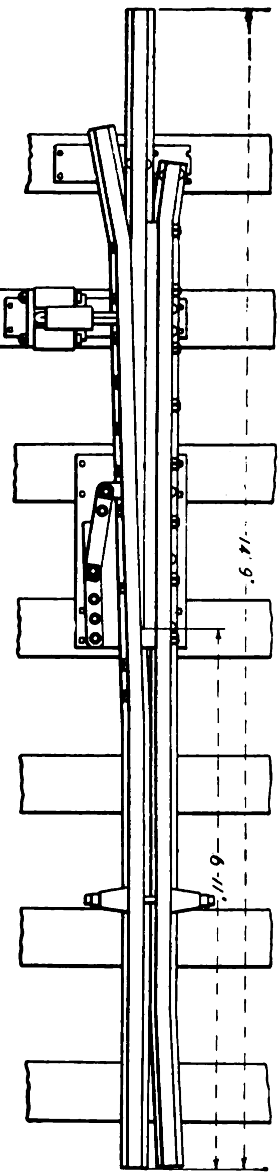


Fig. 167.—No. 25 "Single-Pointed" Weir Spring-Rail Frog.

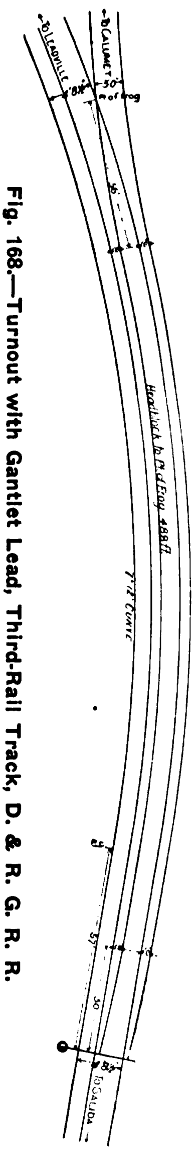


Fig. 168.—Turnout with Gantlet Lead, Third-Rail Track, D. & R. G. R. R.

sloping side easily move the wheel over to place, which of course acts to pull over the opposite wheel. The guard G should be well braced.

The improved Wharton switch is made entirely of T-rail and is usually about 18 ft. long. Figure 171 shows the form used on the Cleveland, Cincinnati, Chicago & St. Louis ("Big Four") Ry. Instead of the grooved rail a guarded point rail forms that side of the switch. This serves to prevent the wheel flanges on the opposite side from riding the main rail. In place of the catch guards (F and G), described in connection with the previous figure, two plain guard rails are employed. That at the end of the point rail is intended to form a continuation of the guard bolted to the point rail; that on the opposite, or frog, side makes it certain that when a train is entering the turnout the wheel treads overlap the main rail far enough to catch the outside switch rail. It also guards wheels trailing out of the switch while they are coming down off the high rail and relieves the

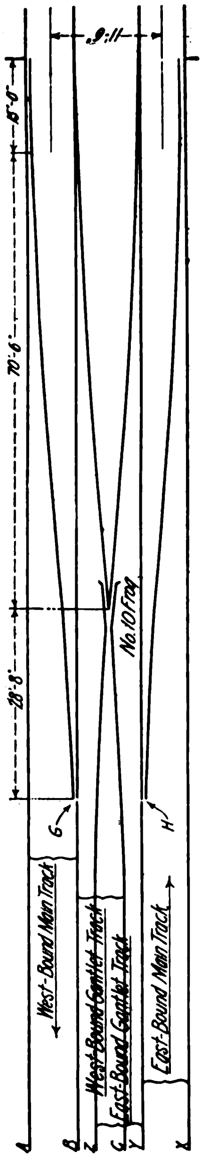


Fig. 171 A.—Gantlet Track for Temporary Use in Musconetcong Tunnel, Lehigh Valley R. R.

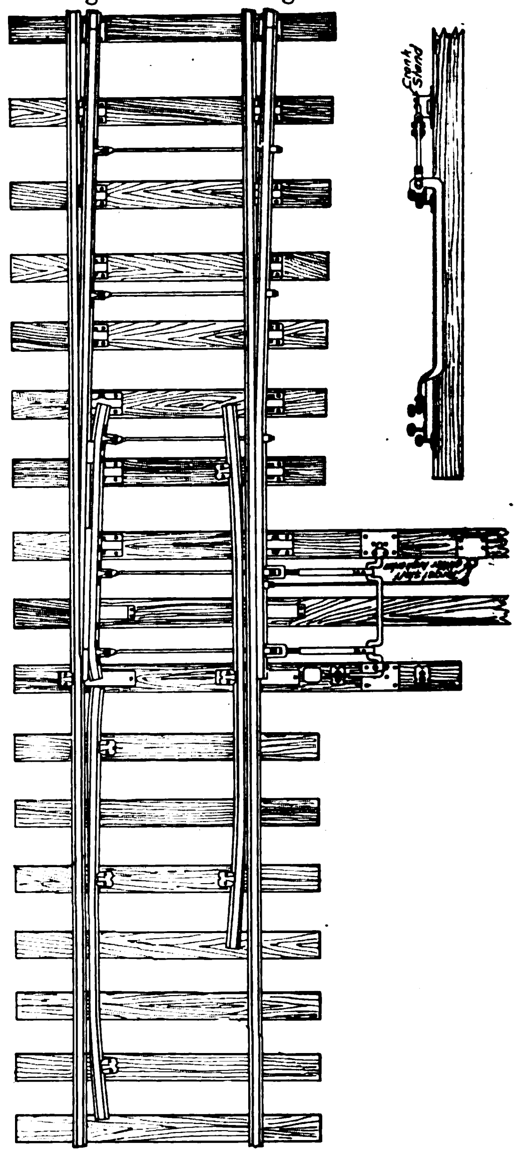
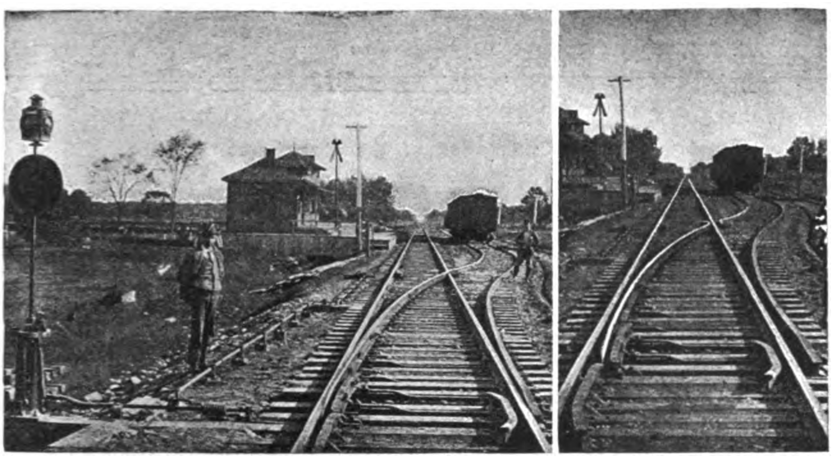


Fig. 171.—Improved Wharton Switch, C., C., C. & St. L. Ry.

main rail on the opposite side from side pressure. It is evident that this arrangement, unlike the catch guards, will not prevent the derailment of a train running out of the siding through an open switch. The movable guard or automatic trip rail is not always used. As used in Austria, the point rail is made shorter than the outside switch rail, and the latter extends farther ahead on the track. When a wheel is coming out of the switch the guard rail at the end of the point rail is thus enabled to hold it (the wheel) before it leaves the outside switch rail. By duplicating the parts for opposite rails the Wharton switch is made three-throw.

Owing to its bulkiness and its cost the Wharton switch has never come into what may be termed general use. For shunting or flying in cars rapidly it is not as satisfactory as the point or the stub switch; and in fact derailments have happened to trains coming out of the switch at speed which would have been safe over a point or stub switch. It has, however, long been in use on a few roads, and there can be no question as to its superiority to all others in point of safety to trains on main line. For outlying turnouts infrequently used, especially at high-speed points, it is unquestionably the best. As the switch has no contact with the main line when not in use it is subject to but very litle wear, and the main-track rails are free to expand in either direction without fouling the switch rails or shoving the switch rods against the ties. It is therefore an economical



Set for Siding. Set for Main Line.

Fig. 172—Mac Pherson Switch, Canadian Pacific Ry.

switch to maintain, so far as attention and cost of repairs are considered. For turnouts from the outside of curves, where it is particularly undesirable to break the rail, the Wharton switch is the remedy, and is frequently recommended for such locations. For many years previous to 1901 this was the standard switch of the Chicago & Alton Ry., and was used on the whole length of the road. It is now in use to at least some extent on a goodly number of roads, being the standard switch on the Mexican Central Ry., the standard switch for main track on the Plant System, and one of the standard switches of the Cleveland, Cincinnati, Chicago & St. Louis, the Delaware, Lackawanna & Western, the Pennsylvania Lines West and other roads.

The underlying principle of the Wharton switch is so sound that several modifications of the device have been adopted in the practice of late years. An interesting example of this kind is the MacPherson switch, designed by Mr. Duncan MacPherson, division engineer with the Canadian Pacific Ry.

Figure 172 shows the switch in both the open and closed positions, as used on this road. In this particular instance the switch is used with a MacPherson frog (Fig. 94), the two being interlocked. As may be seen, the switch is constructed on the Wharton principle, having a point rail on one side of the track and a raised switch rail sloped at the end, for lifting the wheels over the main rail at the other side of the track. As used on this road the connecting rod is rigidly attached to the switch in ordinary use, but in case the switch is set the wrong way for a trailing train the forcing of the points will shear a split pin and bring a spring into play, so that the points are not damaged by being forced open, and a record is left showing that the switch has been improperly used. Referring to Fig. 173, it will be seen that there is an adjustable spiral spring coiled about the connecting rod, one end of the spring being attached to a lug held to the connecting rod by jam-nuts and the other end to a turned-up end of the head switch rod. The end of the connecting rod projects through the turned-up end of switch rod No. 1 and terminates in a flat piece ½x⅞x3 ins. long. Through this flat terminal there is a ⅜-in. pin which, in the ordinary condition of affairs, holds the connecting rod and the head switch rod in rigid connection, and the spring does not come into service. When, however, the points are forced aside by trailing wheels the pin is sheared and the points are forced open against

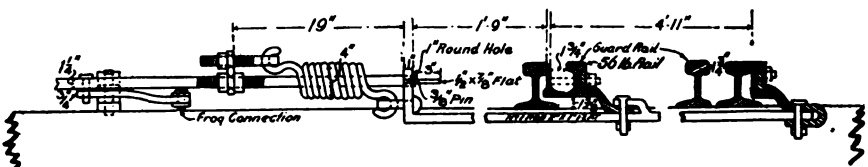


Fig. 173.—Spring Connection of the MacPherson Switch.

the tension of the spring, which then serves to return the points to their original position after the wheels have passed. The engraving also shows a section of the switch rails opposite the switch stand. The two inner rails are guard rails, the 56-lb. rail being attached to the point rail and the other guard rail being set so as to hold the wheels well over toward the sloping switch rail (see also Fig. 172). This sloped rail, which serves to elevate the wheels opposite the point rail, is reinforced by a ¾-in. strap, as shown. As used on the Canadian Pacific Ry., these switches are laid in ordinary main-line turnouts but not at junction points or in turnouts where the siding is used as frequently as main line. They are also in service on numerous other roads, among which are the Boston & Maine, the St. Lawrence & Adirondack, the Southern Pacific, and the Canada Atlantic.

74. Derailing Switches.—Where the grade of a side-track descends toward the switch it is unsafe to leave cars standing upon it without some reliable means to prevent them from running out and fouling main-line trains, in case they break loose. Under favorable conditions cars might be expected to start unaided on a grade of about four-tenths of one per cent, but wind will start cars down an easier grade, and heavy wind might start them on the level. The setting of brakes should not be depended upon to hold cars that are left alone; and so, wherever there is likelihood that cars on side-track may start from gravity or be blown or easily pushed, the only safe policy is to provide for derailing them before they can get far enough to obstruct main track. If the side-track is used exclusively as a passing siding the rule does not apply.

A derailing switch may consist of a single moving rail connected with a switch stand, on a headblock; although it is better, if it is much used, to put in a headshoe. Sometimes two moving rails are used, the same as in a stub switch. One moving rail is all that is required to derail the car, but the use of two facilitates hauling the car back again. The lower engraving of Fig. 174 shows the derailing switch with a single moving rail set for derailing. A single moving rail should heel toward the frog and the rail should be thrown inward, as shown in the figure, so as to guide the wheels away from main track. In side-tracks it is placed in the outer rail, or the one farthest from main line. In the derailing position it should be backed by a few rail braces near the end, as at *A* in the figure. When two moving rails are used they may heel either toward the frog or in the opposite direction, as suits convenience. When they heel toward the frog they should throw inward, but when they heel the other way they obviously should throw outward.

A single switch point with a bent stock rail, the switch point heeling toward the frog and throwing inward for derailment, is the device most extensively used for a derailing switch, being the usual standard for main-track derails near interlocked crossings. The point rail, in its position for derailment, should be backed by two or three rail braces. If a spring connecting rod or Lorenz spring be used with the point rail, as appears in the upper engraving of Fig. 174, a car entering the side-track may pass over the point in the open position without breaking it or the connection. Switch points for derails may be made more blunt (of larger angle) than those commonly in service in turnouts, but for derails in side-tracks old point rails too badly worn for further service in main track may be used. The throw of the stand should be such that a derailed wheel may pass between the point and stock rails without spreading them apart. At the heel

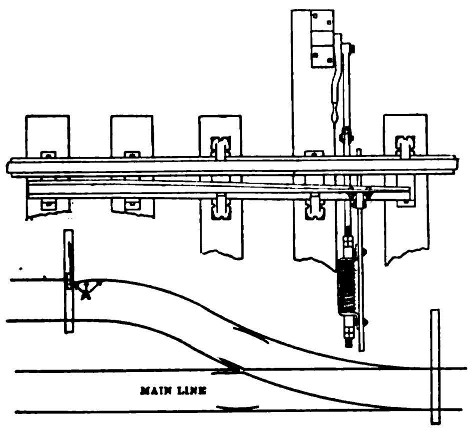


Fig. 174.—Derailing Switches.

of the point rail the nuts of the splice bolts should come on the gage side, There have been numerous instances where the leading derailed wheels have sheared the nuts outside the splice, thus permitting the wheels following to force in the point rail, mount the main rail and proceed thereon. One objection to the use of a switch point derail in main line is that the rail is broken on one side of the track, and where rails creep badly the derail may frequently be thrown out of adjustment. A remedy for trouble of this kind is a heavy anti-creeping casting bolted rigidly in between the main rail and the bent stock rail behind the heel of the point rail.

The derailing switch stand need be only a ground lever. When cars are standing in the side-track unattended it should always be set for derailing, and by all means it should be kept locked. In side-tracks much used, however, the only proper arrangement is to connect the derail with the main-line switch or stand. The derail is closed when the main switch is opened and, vice versa, it is opened when the main switch is closed. This

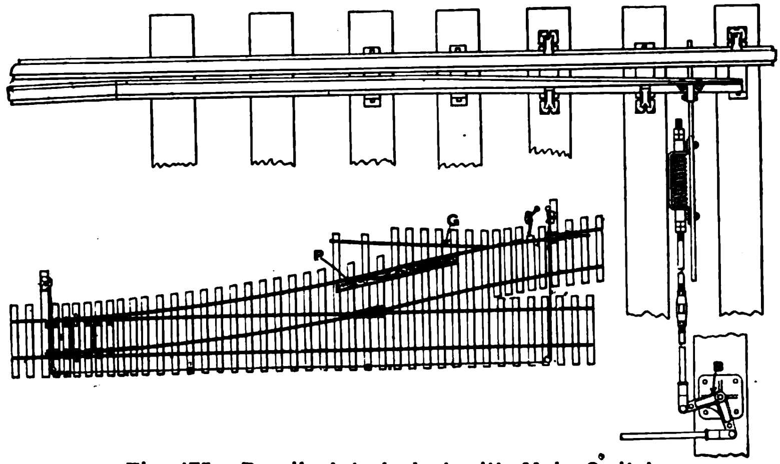


Fig. 175.—Derails Interlocked with Main Switch.

method assures that the derail will be always properly set, and it avoids the inconvenience which otherwise would result from having to throw the extra stand each time the side-track is used. The connection is usually by means of throw rods and bell crank (*B*, Fig. 175). The lower engraving of this figure shows an Elliot lap switch derail connected with the main switch by a cable. When the main switch is closed this cable pulls open the derail, and when the main switch is opened the derail is closed by a weighted lever arranged as shown. The same derail is also installed with a pipe-line connection, which gives positive action both ways. On the Southern Pacific road derails are put in all sidings which descend toward the switch on grades of 21 ft. per mile or over, and the derail is thrown independently of the main switch. To remind the man who opens or closes the switch, of the derail, there is a derailing switch notice sign attached to the target shaft of the main-line switch stand, with the sign facing the throw lever. This sign is a cast iron plate 8x10 ins. x $\frac{1}{2}$ in. thick, with a rim $\frac{3}{8}$ in. thick, painted white, with black letters reading: "Attend to Derailing Switch."

Among other derailing devices the Wharton switch, shortened in length and simplified in construction, is used a good deal in main track

Fig. 176.—Wharton Throw-Off, Philadelphia & Reading Ry.

in connection with interlocking. It is known as the Wharton "throw-off" and is shown in Fig. 176. When set for clear running if affords the important advantage of an unbroken track, thus insuring safety, smooth running and no wear from traffic. As it is operated with a 6-in. throw, it is, when open, well out of the way of passing wheels, with no chance for the traffic to run afoul of a slightly opened point. For use on curves, where it is usually undesirable to break the rail and put in a switch point, the Wharton throw-off is particularly well adapted. There are some conditions, however, under which the Wharton derail is liable to give trouble. Derails of this type which turn to the inside of curves will not always act where the outer rail of the curve is badly flange worn. Where the side and top corner of the rail head was much worn the wheel flanges, which tend to crowd the rail, have been known to pass behind the switch point and not follow the derail. To overcome such difficulties as this it has been the practice on some roads to renew the outside running rail of the curve every six months.

The Dailey automatic "cut-out" switch (Engr. *T*, Fig. 177), designed by Mr. A. G. Dailey, superintendent of tracks with the Michigan Central R. R., where it is in extensive use for derails in side-tracks, consists of a

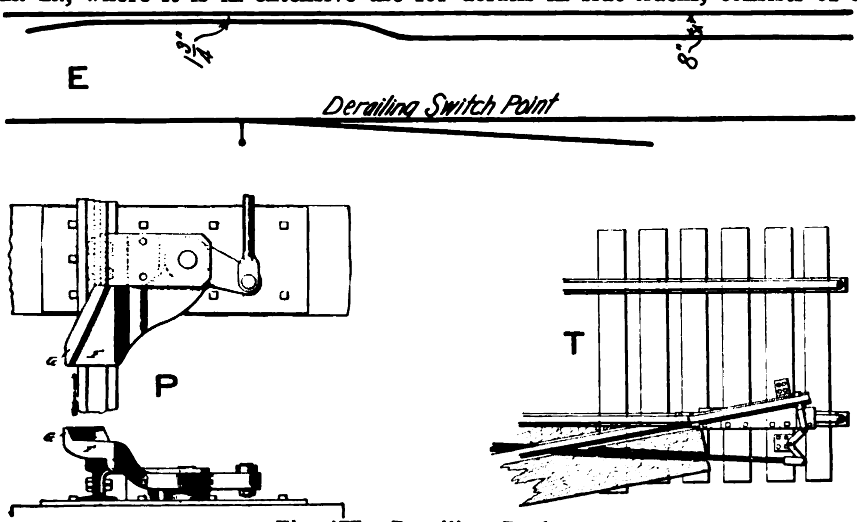


Fig. 177.—Derailing Devices.

swing rail about 5 ft. long heeling toward the frog and throwing inward in the track. It is connected with the main switch by means of pipe line and bell cranks, which open the derail when the main switch is closed and set it for passage when the main switch is opened for the side-track. The piece of swing rail is hinged to a heavy base plate, which extends between and under the ends of the fixed rails, there being a shoulder at each connection to prevent the fixed rails from closing in on the swing section when expansion or creeping occurs. At the heel of the derail, on the outside of the track, an old switch point is laid to deflect derailed wheels from the ties and away from main line. The web of this deflecting point rail is cut out for the pipe line and the latter is protected from being cut by derailed wheels by planking. This device is also in service on the Grand Trunk Western, Pere Marquette and other roads.

In connection with derails mention may be made of the scotch block, two forms of which are shown in Fig. 178. This device is used in connection with interlocking apparatus and is often substituted for a derailing switch, on side-track, where it is desirable that cars shall stand as near the fouling point as possible and still be prevented from running out upon main track. In case the car should strike the block at good speed it would, of course, be derailed. The chock is pivoted to a bearing piece securely bolted to the rail, and the manner in which it is thrown back or moved into the "reverse" position to permit the passing of a train is made clear by the appearance of the pipe-line throw rods. At the right-hand side of the illustration the chock is shown in connection with a detector bar, which will not permit it to be thrown under a car or train or immediately in front of a car or locomotive. The Travis derail (Fig. 177, Engraving *P*) consists of a scotch block pivoted to a plate outside the track and swung over the rail for the derailing position, as it appears in the figure. The front *F* is beveled down and there is a rib *G* running diagonally, so as to catch the flange and carry the wheel athwart the rail. It is used in interlocking work, and is especially serviceable on curves too sharp for the convenient use of a point rail or where a guard rail inside the outer rail of the curve will not permit of a point rail being used. Like the Wharton throw-off, it overcomes all the objections which stand against the use of the point or split rail in such places. The main or movable part is a heavy malleable iron casting weighing 61 lbs.; the whole apparatus weighs 170 lbs. The Smythe derailer consists of a steel casting hinged to a base piece at the side of the rail, in a manner to flop over and rest upon the rail for the derailing position. The top of the casting has a diagonal groove which carries the wheel flange across and off the rail.

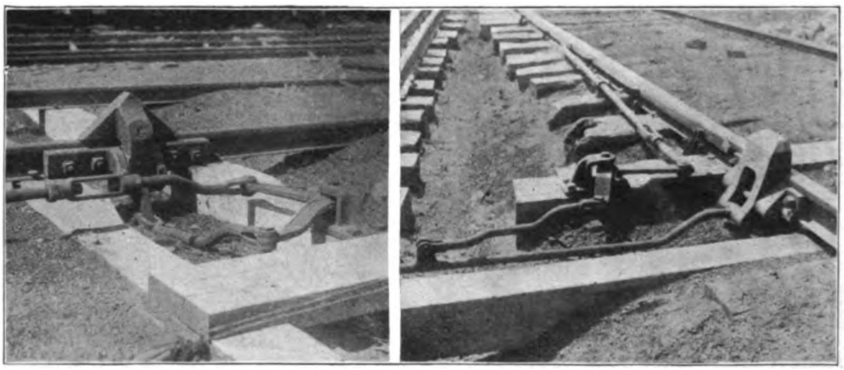


Fig. 178.—Scotch Blocks.

Wherever a derail is used in main track it is desirable to prevent, as far as possible, the ditching of derailed trains. In order to hold the wheels to the ties a long guard rail should be laid in the track about 8 ins. from the opposite rail, extending from a point in advance of that where the wheels are derailed. Figure 176 shows two guard rails for this purpose. In side-tracks, the object of the derail being to prevent obstruction to main line, the derailed car must be diverted, and it is not desirable, therefore, to use a guard rail for holding the wheels to the ties. In such places, however, it may save damage to derailed rolling stock, and facilitate the work of hauling it on the track again, if a short stretch of smooth, unobstructed ground is provided in the vicinity of the derail. In case the derail comes on a fill the embankment should be shouldered out to a respectable distance from the ends of the ties. To place a derail in track where the embankment slopes rapidly from the ties, as one may sometimes see, has the appearance of "looking for trouble."

On some roads point derails in main track are protected in the closed position by a guard rail placed opposite and set to the ordinary distance

(4 ft. 6½ ins.), as in laying a guard rail opposite a frog. This guard rail (Sketch *E*, Fig. 177) extends from a point a few feet in advance of the derail, and the flangeway holds to standard width (1¾ or 1⅞ ins.) some 3 or 4 ft. in rear of the point rail end, where the guard rail flares rapidly, so as not to interfere with the function of the derail when set for derailing. Usually this guard rail is continued, at a distance of about 8 ins. inside the running rail, in position to hold derailed wheels to the ties, as above noted. Although point-switch derails in main track are usually, if not always, secured in the closed position by a point lock, the purpose of a guard rail opposite is, of course, to prevent wheel flanges from crowding the end of the point rail when it is closed. On double track, derails are placed in an outer rail, so as to avoid obstructing the other track in case of derailment. This arrangement sometimes brings the derail on the inside rail of a curve.

Where a side-track derail is interconnected with the main-line switch or switch stand a brakeman will quite frequently forget about the derail when a car or train is entering the turnout, and close or attempt to close the switch immediately the last car passes over it. If he succeeds in latching the stand before all the wheels have passed the derail the latter will usually be set over by the trailing wheels at the cost of broken or bent throw rods, in case the connection is rigid; but if he is not quick enough, in the interval between the passing of the wheels, to get the derail fully

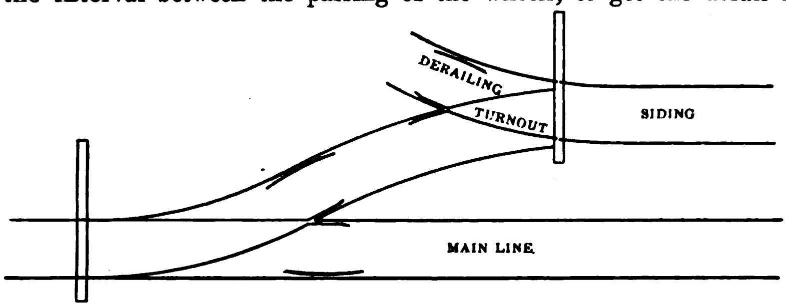


Fig. 179.—Derailing Turnout.

open and the stand latched, he is quite liable to suddenly meet with rough handling at the end of the throw lever; in fact persons attempting to close a switch under circumstances of this kind are sometimes injured more or less seriously. Damage to the throw rods may be prevented in cases of this kind by a spring connection with the derail, as by a Lorenz spring (Fig. 175), but trouble for the brakeman can be avoided only by the use of a detector bar (Fig. 224, described further along), which should be placed between the main switch and the derail, and which will not permit the latter to be thrown until all the wheels have passed. As, however, the installation of a detector bar is a matter of considerable expense it is not usually provided in side-tracks. Such being the case it is pertinent to observe a danger in the way of connecting a derail with a main switch or stand working on the automatic "set-over" plan. In case such a stand should be latched before a car entering the turnout has passed the derail the wheels trailing the derail would automatically throw the switch and stand and leave the switch set in the wrong position. Instances are also conceivable where trouble might arise with automatic "fly-back" stands operated in the same manner. The safest stand for such work is, therefore, a rigid one.

Where considerable headway may be attained cars might, unless derailed a good distance back, run over the ties far enough to foul the main track. So where the grade of the siding is a long one, or steep, like a siding for coal chutes, for example, something more than simple derailment is necessary. Figure 175 shows an arrangement whereby the derail may be located near the main line switch and still throw cars a good distance clear. There is a deflecting guard rail *G*, and a plank *P* placed so as to run the wheels over the rail. The surest and best way of accomplishing the purpose is to lay a derailing turnout or stub track, as shown in Fig. 179. As the arrangement is intended for use only in emergency cases, old material can be worked up in this way to good advantage. When the track is extended beyond such a turnout the contrivance is known as a "diverting track" or "catch siding." Such are sometimes used in main track, for purposes explained presently.

Catch Sidings.—For stopping runaway cars or trains on heavy grades, without derailing, resort is sometimes had to catch sidings. A notable example of such provision is to be found on the Canadian Pacific road, between Hector and Field, B. C., near the summit in the Rocky Mountains, where there is a nine-mile grade of 4.4 per cent. Along this grade there are spur tracks or "blind sidings" one mile apart, each tended by a switchman. Each spur track runs up into the mountain side several hundred feet on a very steep grade which rises in the direction in which the grade of the main track falls. Normally the switches are all set for the side-track and are not closed for main track unless called for by whistle. Hence if a train or detached cars get beyond control and come down the grade they are diverted to a heavy up grade at the first switch, without giving any signal. As the speed at which runaway cars are liable to enter such a siding is high the curvature of the turnout should be easy and the angle of the switch points small. Wherever it is feasible to do so, it would be well to have the

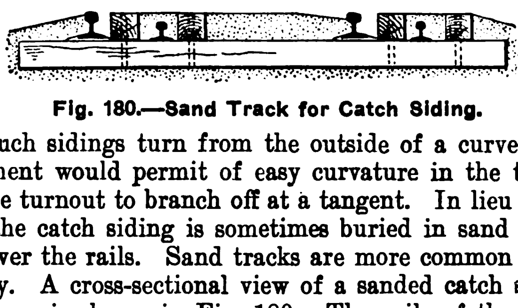


Fig. 180.—Sand Track for Catch Siding.

switches for such sidings turn from the outside of a curve in main track. This arrangement would permit of easy curvature in the turnout, or perhaps enable the turnout to branch off at a tangent. In lieu of the up-grade arrangement the catch siding is sometimes buried in sand to the depth of a few inches over the rails. Sand tracks are more common in Europe than in this country. A cross-sectional view of a sanded catch siding in use at Dresden, Saxony, is shown in Fig. 180. The rails of the diverting track are laid gantlet fashion, on the same ties with the main rails, and the stretch of diverting track is provided at both ends with a switch for connecting with the main line. Guard timbers or angle irons for retaining the sand are placed at both sides of each rail of the siding, which gradually dips deeper until it is covered by 2 or 3 ins. of sand. The arrangement is considered very efficient for the purpose. In this particular instance the catch siding is 1640 ft. long and 1148 ft. of the same is covered with sand. In very dry weather the sand is kept damp. The braking effect of sand sidings is discussed in "Engineering" (London, England) for Dec. 10, 1897, and in the Bulletin of the International Railway Congress for July, 1899.

75. Side-Tracks.—A side-track means, of course, any track not used as main track. By the term "spur" or "stub track" is usually meant a side-track which is connected to another track with only one switch. If the freight traffic from a side-track is small, or if it is moved principally in one direction a spur track answers quite well. To suit convenience in switching, a spur track should open out into the main track in the direction in which most of the cars are moved when outward bound. On single-track roads where much traffic is moved from a side-track in both directions, especially if the main track be level at the place, it ought to open out into the main track both ways; such is usually called a "siding." On double track, where considerable traffic is moved in both directions, a spur for each track is preferable to a siding, with its two switches, on one track; and all such spurs are, for both convenience and safety, laid trailing to the movement of the trains.

Wherever it is practicable spurs and sidings used for loading or storing cars should turn out from the main track at a slightly descending grade for a distance beyond the frog sufficient to give clearance from the main line, as under ordinary conditions a derailing switch may then not be needed. The remainder of the length should preferably be level, so that cars may be moved readily with pinch bars. Sidings used for passing tracks should, if possible, be level with the main track or on the same grade with it. To have them lower or higher than the main track often results in a loss of time getting out of or into them with heavy freight trains. Where there is little or no filling to be done, side-tracks may just as well be laid as much as 15 ft. c. to c. from main track, for at least that much space is needed where loading is being done or to give safe room for trainmen working at repairs or attending to hot boxes, between the tracks.

Whenever it can be done side-tracks should be located where a good view may be had both ways along the track. If there is a curve in main track the side-track should be on the outside, as then the view around the curve will not be obstructed by standing cars. Switches should not be located near bridges, ravines, high embankments, etc., when they can well be avoided, as derailment at such points is usually hard on rolling stock. As far as the service will permit, switches from curves should be avoided. In some instances where it is necessary to have the turnout leave the main track on a sharp curve the frog is located at the required point, but a long lead is run back around the curve to bring the switch on tangent. This arrangement is illustrated and more fully described under the subject "Gantlet Tracks," § 77, of this chapter.

Regarding the alignment of the piece of track immediately beyond the frog where a turnout is laid to a parallel track, room and material may be saved by continuing the turnout curve beyond the frog and reversing to bring it parallel at the proper distance. While for spur tracks where but little shifting is done a decreased first cost in this manner might be justifiable, not to consider the room saved, the saving in cost effected by reversing the curve at the entrance of sidings much used for loading or for passing tracks will hardly compensate for the trouble which these reverse curves will give. Where the main line is straight and a No. 9 frog is used, for instance, by continuing the turnout curve beyond the frog and reversing between it and a parallel side-track distant 15 ft. between centers, clearance of 12 ft. between centers may be had in 61.2 ft. from the point of frog, measured along main track; while by continuing the turnout straight beyond the frog for 50.7 ft. and connecting with the side-track by a curve of same degree as the turnout curve (as in the other case), the distance required to give the same clearance is 67 ft.; hence a saving of only 6 ft. of track is effected. It is hardly worth while, then, to attempt to save anything by continuing the turnout curve beyond a frog of number no larger than 9 if the distance between track centers does not exceed 15 ft. Clearance may be had in less distance by making the track straight for some distance beyond the frog than by reversing the curvature at that point. But where the distance between main line and side-track is small the curvature must be reversed at the heel of frog, sometimes, to avoid a curve of too great degree leading into the parallel side-track. It is, perhaps, not advisable to lay the track straight beyond the frog any further than will allow room between it and the parallel side-track for a curve not greater in degree than the turnout curve. This rule might sometimes cut the piece of tangent off pretty short, or cut it out altogether, and thus require the curve to spring from the heel of the frog. As the subject of clearance is again touched upon it may be remarked in this particular connection, that on some roads the clearance point or clearance post is established at the end of the connecting curve which is farthest from the frog; in other words, at the nearest point where the siding becomes parallel to main track. Such practice is defended by the argument that the clearance point, as so understood, is readily and conspicuously definable, even in the absence of a post or other sign of special character; that to designate it at any point nearer the frog is only tolerating encroachment on dangerous ground. When a car "shoved in just to clear" stands at an angle with main track there is no latitude for backward movement, and thoughtless shifting of the car, as with a pinch bar, by some non-railroader, in order to gain a more advantageous position for loading, might lead to trouble. Of course, the question of room and the distance between track centers cuts some figure in the matter, but a derail at the proper point will insure safety without wasting legitimate siding room.

Side-tracks may be laid with culled ties, but they should be full spiked, because they are generally allowed to become further decayed before renewing than are ties in main track. Except under pretty light rail the space between ties in side-track may be increased considerably beyond that required for main line. For passing sidings 12 ties of average size, and for loading tracks 10 ties of ordinary size, per rail length of 30 ft., do well enough on straight line. Old rails can be used with economy, but if the ends are badly battered the battered portions should be cut off before laying. On tracks occupied most of the time by standing cars, rails in almost any condition of wear (so long as pieces of the head are not broken out) are serviceable. On passing sidings a somewhat better class of rail, generally speaking, is required, but rails with heads only moderately slivered or roughened by wear are not objectionable. Side-tracks subject to constant use by locomotives, as the ladder tracks and the main thoroughfares of yards, should be laid with smooth steel not inferior to second-class rails of fair quality; that is, worn rails which would still do in main track but which are sometimes removed in stretches to make room for laying new rails continuously: rails with heads too badly roughened for main-track service should not be used on such tracks as these (A classification of rails is given under "Reports and Correspondence," § 194, Chap. XII). If bolts are scarce and must be used sparingly the two holes nearest the middle of the splice are the proper ones to use. If arranged differently it might so happen that a failure of one of the bolts would leave the remaining one too far from the middle to be of any service. When old spikes are used they should be straightened before redriving, and if the head is greasy time and trouble may be saved by sticking it into the sand or dust before attempting to drive it.

Where old steel is being utilized in laying side-tracks rails of different sections and shapes are quite likely to be found, and quite frequently rails in side-track must be spliced with rails of heavier section, such as are used in main track and laid through the turnout. In order to bring the tops of such rails to the same level and the heads to the same gage at the joints where they meet, step chairs or compromise splices must be provided. Such splices for main track are elsewhere referred to. For use in unimportant side-tracks a cast step chair supported upon a tie is good enough. As the tops of switch ties are supposed to lie in the same plane it is not considered good practice to use compromise splices or chairs on the same. Where the rails in main line and side-track are of different section it is well, therefore, to lay one length of side-track beyond the frog with rails of the pattern used in main track, as above intimated. The same rule would also apply to a change of rail section at a switch in main track. As it is possible for side-tracks to get too rough or uneven, they should be put in good surface and line at the time they are laid and then surfaced occasionally thereafter, particularly when ties are renewed.

Lap Sidings.—On single-track roads it commonly occurs that two trains moving in opposite directions must take side-track at the same place to let a third train pass, and at points where the meeting in this manner is frequent or habitual it is desirable that both trains may enter the siding and leave it without backing up and without interference, such as one of the trains waiting for the other to pull by. One arrangement to permit simultaneous independent movements of this kind is a double siding, the two tracks of which may lie either on opposite sides or on the same side of main line. In the latter case they are connected in ladder style at each end with the turnout from main track. An example of such construction generally followed is to be seen on the relocated portion of the Wyoming division of the Union Pacific R .R. Passing tracks are located at average intervals of 3 miles, and some of these sidings are 8000 ft. long. In almost all cases the sidings consist of two tracks side by side, on the same side of main line, the first one being laid 14 ft. c. to c. from main line, with a view to use for main track in case the road should be double-tracked. These sidings are of sufficient length to permit two long freight trains running in opposite directions to pass a train of superior class, without interference, and if the road should be double-tracked there would still be the outside siding remaining.

From an operating standpoint, however, this arrangement of sidings is not always the most advantageous. Where a train is waiting on side-track time is saved by having the engine stand near the telegraph office, as orders can then be delivered quickly, and as soon as the track is clear the train can pull out without delay. It is also the practice on some roads to place interlocking levers in the telegraph offices or towers for throwing the switches of passing sidings in the vicinity thereof, so that trains may enter or leave the same at good speed without being delayed in stopping to open or close the switch. In order that such methods of operation may apply to waiting trains which are oppositely headed, it is necessary to arrange the sidings on opposite sides of main track and overlapping each other at one end, where the telegraph office may be located conveniently to both switches. Referring to Sketch A, Fig. 181, it will be seen that the arrangement is equivalent to a stretch of double track between the distant extremities of the two sidings (A and D), with a crossover half way between them.

As a general proposition long sidings for single track should be located with a view to future incorporation into main line in case the road should be double-tracked, and for such a scheme the arrangement of lap sidings will usually afford the best economy in grading. When a road is double-tracked most of the sidings previously used for passing tracks are abandoned, or relaid with steel and connected in to be used as one of the main tracks. In the case of lap sidings it usually requires but little extra grading to shift the two side-tracks into line for the double main track; or, if it is desired to maintain a middle siding between the main tracks, the old single track becomes the siding and the old lap sidings are converted into the outside double track, without disturbing the alignment.

A brief reference will be made to some of the plans for locating lap sidings with a view to later change them into main track use without extensive shifting of the alignment. Where the sidings are made to lap each other without changing the original alignment of the main track, as in Sketches "A" and "B," Fig. 181, the arrangement is known as a "plain lap." The distance C to B is called "the lap," and obviously the frogs for the two turnouts should be far enough apart to allow clearance distance between leads throughout the lap, thus permitting trains to pass through both turnouts at the same time. When $C\ B$ is much longer than is required for this purpose it is called a "long lap." Sketch "B" shows the sidings arranged to lap on a curve. So far as the ultimate purpose of the arrangement is concerned it is a much more desirable form than the foregoing, since to double-track the line it would suffice to reline the curve to conform to the broken lines, the outer one of which, as will be seen, is a simple curve between the original line $A\ E$ and the new tangent $G\ K$; and the inner one a similar curve between the east-bound siding and the old main

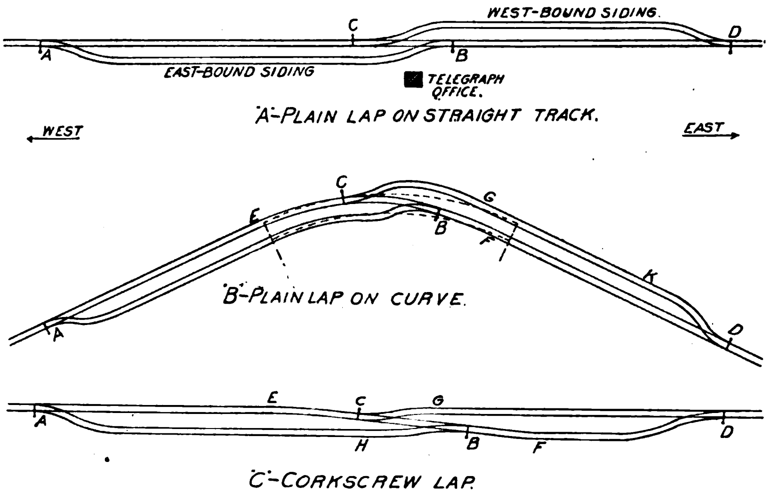


Fig. 181.—Lap Sidings.

line $F\ D$. The new curve could be kept within the tangent limits of the old curve $E\ C\ B\ F$, and practically on the same roadbed, by compounding or spiraling. In the case of double-tracking in Sketch "A" it is evident that one siding must be thrown to the opposite side of main track or else the main track for some distance must take the form of a reverse curve; or the whole stretch of straight track must be relined and thrown to a new location throughout—any one of which is an objectionable plan. To obviate these difficulties the "corkscrew" lap, shown as Sketch "C," is sometimes resorted to. The line $A\ E\ C\ G\ D$ is the original main track simply thrown over at C. The new track $C\ B\ F\ D$ is constructed for the main track in the new position, while $C\ G\ D$ becomes a siding. The curves at E and F are made of small degree with a piece of tangent between them, from which the sidings take their lead. The turnout at D is given a long lead, so as to form an easy curve for the main line. If, however, there be a curve at D, the main track should be lined into the curve and the siding connected in the usual manner. While this arrangement presents rather an odd-looking main-track alignment, it nevertheless requires a minimum of alteration in changing to double track. As the tracks between F and D and between H and A are, throughout most of their length, parallel to the general direction between A and D, it becomes necessary only to cut the crossover and throw the comparatively short portions of curved track at C and B into the alignment of the straight track on either side. In case it was required that the distance between main and side-tracks should exceed the standard distance between double tracks, in order to advance the clearance point of both sidings, it would, in double-tracking, be necessary, of course, to throw nearly the whole stretch $A\ H\ F\ D$ toward $A\ D$ the amount of the excess; but such a change would involve no great amount of trouble with tracks on the same bed. Sidings specially arranged for the convenience of traffic on double-track roads are referred to in the chapter on "Double-Tracking."

76. Crossovers.—A crossover is a double-ended turnout connecting two tracks, and consists of two turnouts facing in opposite directions, connected between frogs by a short piece of diagonal track. If the two tracks are straight and parallel and near together, the piece of track between the frogs should be straight, and consequently the frogs in both turnouts should be of the same number or angle; where the frogs are of different angles the track connecting the two must be curved in an awkward manner, or else one of the parallel tracks must be thrown into a double reverse curve, which is sometimes done in the case of a side-track the alignment of which is unimportant. A condition essential to the satisfactory laying and operation of a crossover between two tracks that are near together is that they shall both be on the same level. If they are not at the same level they should be so placed at the crossover, and for convenience of tamping and tie renewing

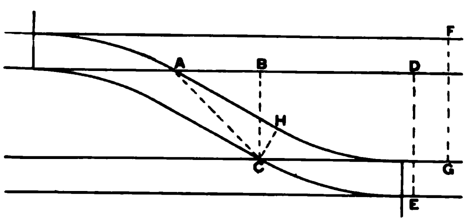


Fig. 182.

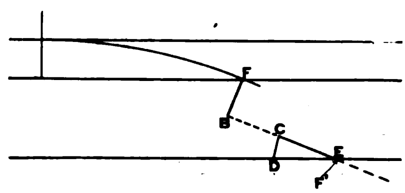


Fig. 183.

the track between the frogs should be laid with long switch ties extending through and under both outside tracks. For tracks at 13 ft. centers this arrangement requires ties 21 ft. long which, however, are not as long as ties sometimes used behind the frogs in turnouts from three-throw switches. The usual arrangement is to lay both turnouts of the cross-over with switch ties of ordinary lengths and use short ties (8 ft. long) under the track connecting the frogs, interlaid with the ends of the ties in the outside tracks.

The method of laying a crossover is, after determining the starting point, simply that of laying a single turnout. This starting point is the point of frog on either track, after the location of the point of frog on the other track has been decided upon. The first point of frog is chosen arbitrarily, but the second must be located at a definite distance from it, depending on the frog angles and the distance between the tracks. After the second point of frog has been located the measurements for that turnout must be taken with reference to that point. On straight parallel tracks the distance between frog points in a crossover may be measured in two ways; either along the parallel tracks, as $A\ B$ in Fig. 182, the line from B to C being perpendicular to the tracks; or by a direct measurement between the two frog points, called the "diagonal distance," represented by $A\ C$ in the figure. The diagonal distance is the simplest to use, since it is direct; whereas, when using the other measurement, $A\ B$, the point C must be established directly or squarely across from B—a method requiring two operations. A rule sometimes used for the parallel distance $A\ B$ is the product of the frog number by the difference between the distance center to center of the two tracks and twice the track gage—

$$A\,B = n\,(F\,G - 2\,g),$$

where n equals the frog number, $F\,G$ the distance center to center of the two tracks, and g the gage of the track. This rule is only approximate, and always gives a distance too long. The correct distance may be found very nearly (within an inch) by decreasing the distance found by the above rule by the quotient of 36 ins. divided by the frog number. It is certainly a near enough rule for business purposes. An approximate rule for the parallel distance where the frogs are not of the same number is to multiply the distance between track centers minus twice the gage, by half the sum of the two frog numbers, or $AB = \frac{1}{2}(n+n')\ (F\,G-2g)$.

The correct parallel distance is the difference between two quotients: one of which is the distance center to center of the two tracks less the track gage, divided by the tangent of the frog angle; the other is the gage of the track divided by the sine of the frog angle; that is,

$$A\,B = \frac{B\,C}{\text{tang}\,F} - \frac{g}{\sin F}$$

The length of the tangent $A\,H$ is found by dividing the distance center to center minus the track gage, by the sine of the frog angle, and decreasing this quotient by the gage of the track divided by the tangent of the frog angle; that is,

$$A\,H = \frac{B\,C}{\sin F} - \frac{g}{\text{tang}\,F}$$

This formula is of use in determining the length of tangent to lay at the heel of the frog before reversing with a curve of the same degree as the turnout curve to bring the side-track parallel with the main line.

The diagonal distance $A\,C$ is the square root of the sum of the squares of the parallel distance, and the distance center to center minus the gage; or

$$AC = \sqrt{[(AB)^2 + (BC)^2]} = \text{also}\ \sqrt{[(AH)^2 + g^2]}$$

Table XV (see index) gives the correct "parallel" and "diagonal" distances, and length of tangent between points of frogs, for different gages center to center of tracks varying by 6 ins., and for frogs of different numbers. For gages c. to c. of tracks intermediate between those given in the table the corresponding frog distances and tangent lengths may be found by interpolation.

Before starting to lay a crossover both the tracks in the vicinity of the crossover should be put in good alignment. The distance center to center of the two tracks is most conveniently and expeditiously found by measuring between the gage lines of rails on the same (right or left) side of each track; that is, either $D\,E$ or $F\,G$, in Fig. 182. A convenient way to find the second point of frog by trial, is to lay the first frog and put down temporarily a straight rail at its heel to line properly with the frog. Then slide a track gage along it, keeping the tool perpendicular to the rail until it meets the gage line of the near rail of the other track. The point where the track gage just reaches is the point of frog. A device called a frog board is also used to some extent. It consists of a triangular piece of board 7 or 8 ft. long, the edges of the board meeting at an angle corresponding to the angle of the frog to be used. After the first frog is laid a track gage is placed across the turnout at the frog point, perpendicular to the line of the frog. The position of the point of the second frog, on the rail of the other track, is estimated roughly, and the frog board is moved along near this point until a string stretched from the end of the gage to the point of the frog board is in line with the edge of the board. With the board in this position the point of the same is at the point of the second frog. The use of the frog board is shown in Fig. 183. *F* is the point of the first frog, or the one put in arbitrarily; *F B* is the track gage; *C D E* is the frog board; *B E* is the string. Slide the board along the rail until the string *B E* can be made to line with the edge *C E* of the board. The point *F′*, or the position of *E*, the end of the board, is then the point of the second frog.

Where the two parallel tracks are on a curve the track between the two frog points of the crossover cannot be straight if the two frogs are of the same number. For slight degrees of curvature and frogs of small number, say No. 7 or less, and the tracks near together, the connecting track may be made straight between the frog heels by using the same parallel or diagonal distances as for straight tracks; but this piece of track will be slightly out of line with the two frogs. But for ordinary frogs of the same number the connecting track between the two frogs on parallel curved tracks (using the same parallel or diagonal distance as for straight tracks) should be curved to a radius which is longer than that of the main line in the proportion of the length of tangent (*A H*) to the parallel distance (*A B*). This curve must then be compounded with the turnout curve at the point of the outer frog and reversed to the turnout curve at the point of the inner frog. Such is better practice than that of extending both turnout curves to a point of reversal somewhere between the frogs. Where, however, there is considerable distance between parallel tracks, room may be saved by reversing the curves between the frogs. For this purpose both frogs may be of the same or of different angle. But by using frogs of different angle the connecting track between them may be made straight, the frog of greater angle being placed in the outer track. In selecting the frog for the outer track it should be borne in mind that it goes in on the inner side of the curve in that track, in which case turnout curvature runs up fast as the angle of the frog increases. There is no simple rule for finding the proper distance between frogs in crossovers between parallel curved tracks, and the problems are so diversified that they will not be taken up here. A practical way of laying such crossovers is to use such a frog in the outer track as will answer to a turnout of suitable curvature. Then tie two strings of equal and sufficient length to the ends of two sticks, each of which is equal in length to the gage of the track. Stretch out the two strings, keeping the parallelogram rectangular and holding it so that the outer string lines straight with the frog already laid or with a frog board placed at the point chosen for that frog. The point where the other string crosses the gage line of the near rail of the inner track will be the point of the second frog. Such measurements can then be taken from string to rail as will determine the angle of this frog. Plotting the crossover to large scale is the readiest method of getting the measurements in the office.

On double-track roads, crossovers are laid trailing to the movements of the trains. This arrangement requires the trains to "back over," but in using the crossover to clear the track for a following train it really effects a saving in time, since it gives the flagman who goes out ahead a start equal to the train length before the train can back over; and after the train following has passed, the train which has backed over can pull straight ahead. But aside from these advantages, the element of safety is with the trailing switch. The two switches of crossovers are sometimes connected with one stand placed midway the crossover. In other instances a stand is sometimes used at only one switch of the crossover, the other switch being operated by a pipe line and bell crank connection between the two. Either arrangement is especially useful in busy yards where the switches are thrown by hand, as it saves the time that would be required for the switchman to run from one end of the crossover to the other if a stand was used at each switch.

77. **Crossings.**—At the crossing of two tracks four frogs are required. The manner of constructing these frogs depends largely upon the angle at which the tracks meet. Crossing frogs are sometimes referred to as single or double-pointed; but unless these terms "single" and "double" are understood they are liable to lead to confusion in other connections. A frog can have but one point, which, real or imaginary, must be the intersection of the two gage lines. Figure 184 shows the outline of a crossing of two straight tracks. There are four frog points: F, F', F'', and F'''. The angles at F and F'' are acute and equal and those at F' and F''' are obtuse and equal. The frog angle at F is the angle $A\ F\ B$ and the point pieces are $A\ F$ and $B\ F$. The frog angle at F' is $A'\ F'\ B'$ and the point pieces are $A'\ F'$ and $F'B'$. The wing rails of the first-mentioned frog are $G\ E$ and $C\ D$; those of the second-named are $G'\ E'$ and $C'\ D'$. The two frogs shown as F and F' are each ordinary frogs, in no way different except in their angles, the same being supplements of each other. Now when a wheel approaches in the facing direction a frog of ordinary angle, the wing rails forming the mouth of the frog

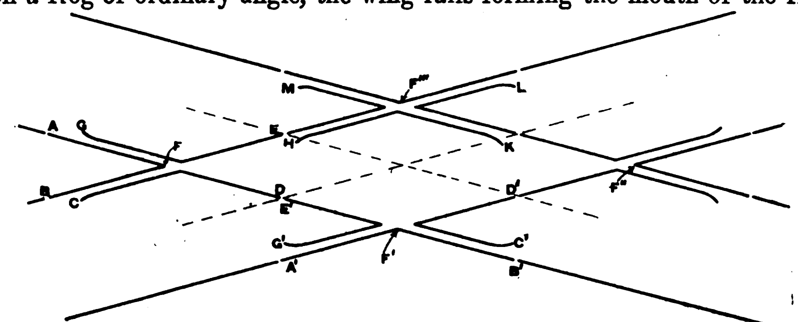


Fig. 184.

guard the flange before it reaches the throat; but if the frog angle be large, as at F', the wing ($C'\ D'$) will not guard a wheel flange (approaching from E') until after it has passed the throat; and the same with the wing $G'\ E'$ for a wheel approaching from D'. Hence in frogs of such large angle there must be two guard rails or wings not required by frogs of ordinary angle in order to guard the wheel flanges in advance of the throat. These guards are placed in the mouth of the frog, like the piece $H\ K$ for the frog F'''. They belong also with the frog F', but have been omitted in the figure for sake of clearness of description. It is this piece $H\ K$ which gives rise to the name "double-pointed," but it constitutes two guard wings, and, using the conventional names for frog parts, the frog is double-guarded or double-winged, rather than double-pointed; the double points referred to being the sharp angles in the wing rails. With this understanding, however, and in deference to common practice, we call it double-pointed. As names denoting the positions of the frogs in the crossing, it is quite largely in vogue to call the frogs F and F'' the "end" frogs and F' and F''' the "middle" frogs. At a crossing of straight tracks the angles about all the four frog points are the same as those about the intersection of the center lines of the tracks; but if one or both of the tracks be curved at this point the angles at the corners will all be different. The angle at each point is, of course, the angle made with the tangent of the curve at that point, and, as previously noted for other special problems of like nature, the readiest method of solution is to plot the tracks to large scale and take the angles off the drawing. Crossings on curved track are usually avoided, if possible. On foreign roads it is quite customary to introduce a piece of tangent at the crossing.

Construction.—In a general way, four styles of crossing construction are recognized. For crossings of small angles—15 deg. and less—the usual arrangement is that of "disconnected frogs." The end frogs are of ordinary construction and ordinary length, and there are connecting rails between these and the middle frogs. For angles of 8 deg. and above, the middle frogs are usually double-pointed, but for smaller angles use is made of movable-point frogs referred to more in detail further along. For angles between 15 and 35 or 40 deg. the crossing is usually made in four sections, the end and middle frogs meeting at joints all around, as in Engraving *A*, Fig. 185 (Weir Frog Company's crossing patterns). This style of crossing is known as "long-angle construction." The fourth style is known as "short-angle construction." In this style, which is usually employed for angles of 35 or 40 deg. and higher, the rails of one track are continuous over the frogs, or throughout the length of the crossing, with the rails of the other track butted against them as arms. If the crossing is made as a single section, known as a "through rail" crossing there are no joints between the corners, as in Fig. 186 (Elliot Frog & Switch Company's pattern); if it is made in two sections, for convenience of shipment, the crossing is cut in two at

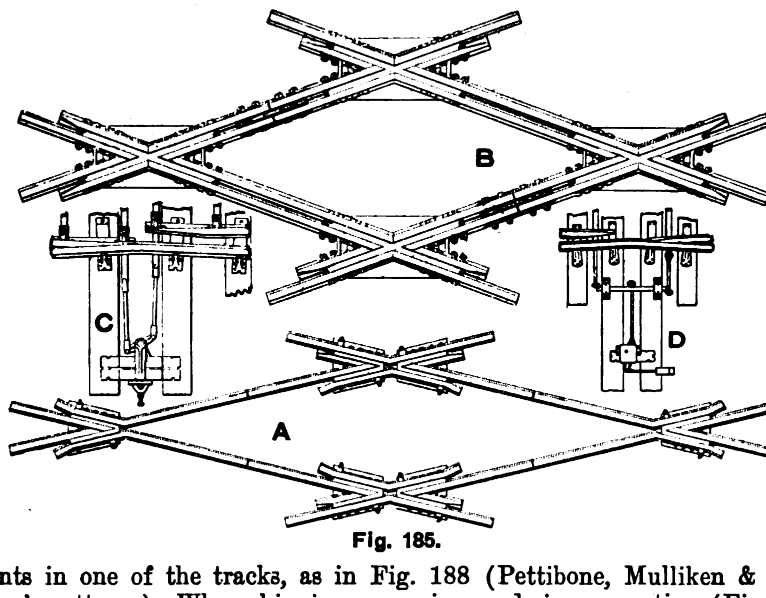


Fig. 185.

joints in one of the tracks, as in Fig. 188 (Pettibone, Mulliken & Company's patterns). When shipping a crossing made in one section (Figs. 186 and 191) either two or four arms are usually taken off. It should, of course, be understood that in designating types and styles of construction the relation of the angles to the various conventional terms and to the range of application of certain details should be taken broadly. Each manufacturer has his own standards in these respects, and among the railways there are no generally recognized standards for frog and switch construction.

For short-angle construction the end frogs are usually double-pointed, and such is also frequently the case with long-angle crossings. The guard rails are then extended from the four corners and joined, or are made continuous, forming what is called a "double-rail" crossing, illustrated by Engraving B, Fig. 185, and by both engravings in Fig. 188. Figure 192 (Ramapo Iron Works patterns) shows the double-pointed end frog for a double-rail crossing at an angle as small as 20 deg. Engraving *A*, Fig. 185, shows a "single-rail" crossing. If the inside guards of a double-rail cross-

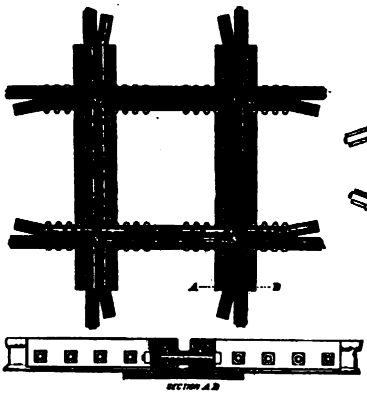


Fig. 186.

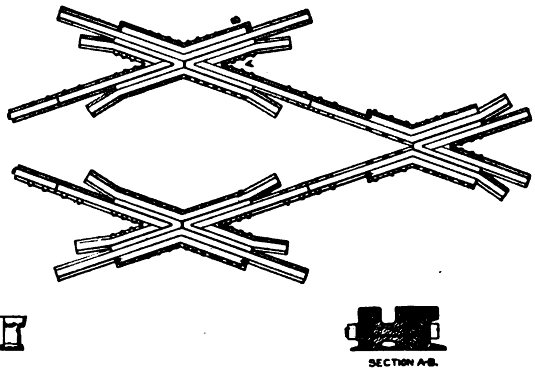


Fig. 187.

ing are not continuous they should preferably break joints with the running rails, as in Fig. 189 (Paige Iron Works pattern), and the filler blocking should break joints with both. In a short-angle crossing with double track the arms between the tracks should be made of proper length to fit without connecting pieces, and preferably without a joint in either guard or running rails. An important modern improvement in crossing construction is the use of reinforcing rails with easer ends, to carry the outer flange of worn wheels. Figure 187 shows the application of this feature to the obtuse corners of a long-angle crossing, and Fig. 189 shows a crossing with reinforcing rails throughout. In this case the easing rails in the outer corners break joints with the main rails, thus affording very rigid construction.

As the flanges of street-car wheels are usually smaller than those of steam cars, the flangeways in a street railway track crossing a steam road may be narrowed accordingly, and much to the benefit of the crossing for the steam cars. The situation is also improved by narrowing the gage of the street car track over the crossing about $\frac{1}{4}$ in., as such steadies the motion of the street cars and reduces the flangeway otherwise required. The crossing of a steam road with a street railroad is sometimes made by leaving the rails of the steam road undisturbed, except to cut notches across them just deep enough and wide enough to let the street car flanges through. The street railway rails are then butted against the steam-road rails and

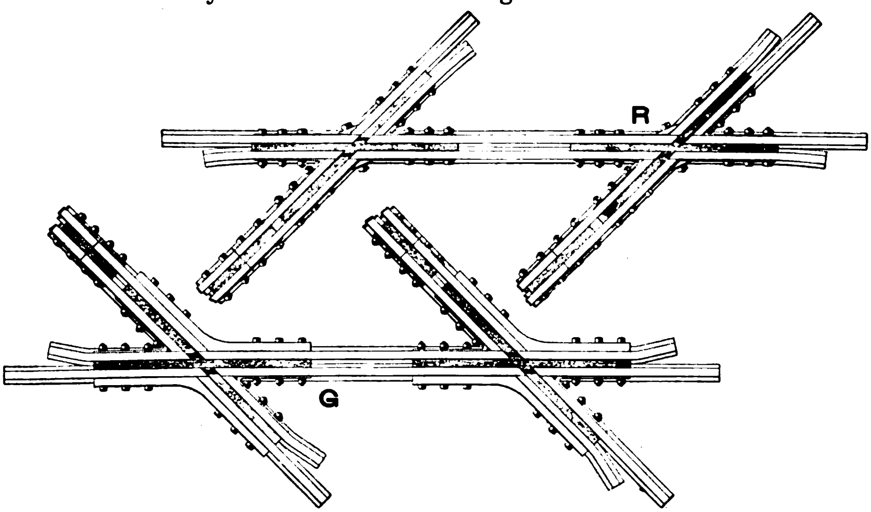


Fig. 188.

bolted to them by splices fitting the angle. The street railway rails must be broken for sufficient distances to make room for the steam road flangeways and guard rails. When the rails of the steam road become battered at the notches they can be removed and new ones substituted without tearing up the crossing. The best form of crossing for steam roads and street railways, however, is one wherein the rails of the steam road are reinforced throughout the length of the crossing, as such reduces the battering at the notches. Such a crossing is shown as Fig. 191. The sectional view shows how the flangeway along each street-car rail is made by planing out a groove in the head of the guard rail for the same, which is laid touching the head of the main rail and solidly bolted to the same through filler pieces. A flangeway for the street railway 1 in. to $1\frac{1}{4}$ ins. wide and $\frac{3}{4}$ to $\frac{7}{8}$ in. deep is usually ample. Such crossings are preferably built entirely with T-rails of the section used on the steam road. The compromise splices necessary to connect with the rails of the street railway, which are usually of the girder type, then come outside of the crossing, and such construction is more satisfactory than that of joining the two kinds of rail together in the crossing. By careful measurements the bolt holes in the rails of the steam road may

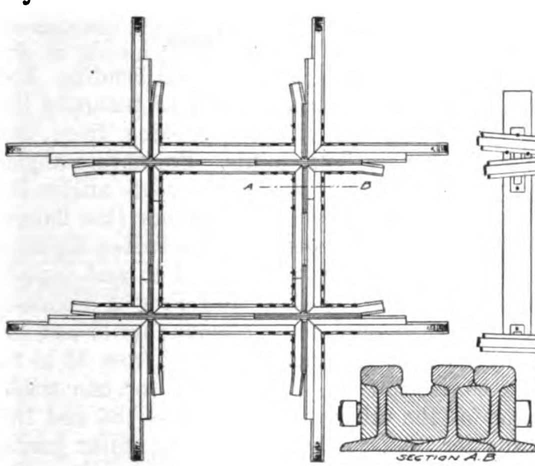


Fig. 189.

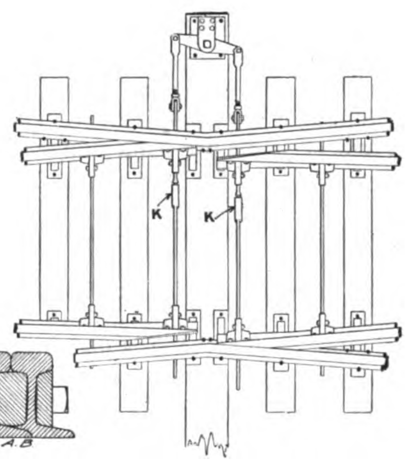


Fig. 190.

be drilled in the rail in place and the crossing then laid without tearing up or obstructing the steam road. The notches are readily cut out of the rail head with hack saw and cold chisel. The rails in the steam road should be continuous over the crossing, even in the case of a double-track street railway. If a joint happens to come within the crossing as located, the rails may readily be cut and moved along to bring the joint off the crossing. When renewal of the crossing becomes necessary the rails for the steam road may be drilled and notched beforehand, ready for laying in place as soon as the time comes for the change.

In long-angle construction it is largely the practice to bend the wing and guard rails to the obtuse angles. Rails for crossings are frequently bent 25 deg. and sometimes 35 deg., and perhaps even more than this in a few instances, but objections are raised to heavy bending, for two reasons: First, a rail cannot be bent to a well-defined angle, and, secondly, the heating of the rail, which is necessary for heavy bending, softens the metal right at the point where the wear is heaviest. Aside from the angle, the necessity for heating rails when bending depends upon the hardness of the metal and the size of the section. Under average conditions in these respects a rail can be bent cold to an angle of about 15 deg. as the maximum. The observation of some authorities is to the effect that the bending of rails for

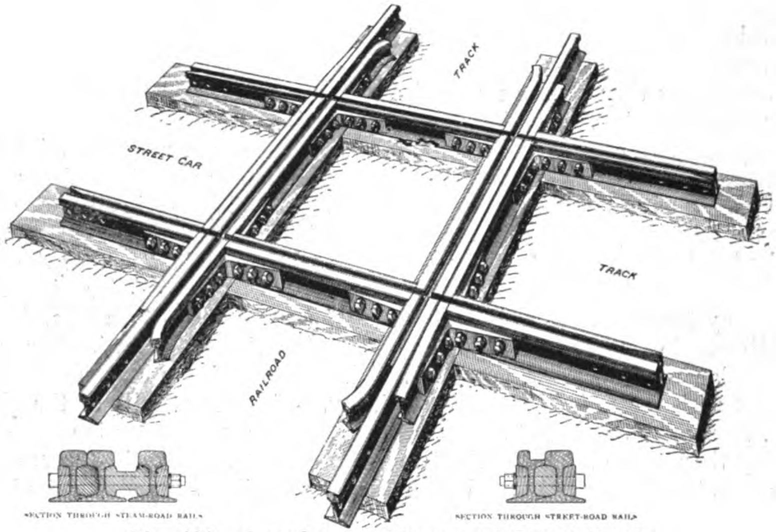


Fig. 191.—Crossing for Steam and Street Roads.

crossing frogs should be restricted to the limitations of cold bending. For angles higher than this they consider a well spliced joint as generally the preferable arrangement. In assembling the arms of crossing frogs two kinds of joints are made, namely miter and butt joints. For obtuse angles the miter joint is perhaps the most common style and for acute angles the butt joint, but when the rails in one of the tracks are continuous (the flangeway being cut through the head only) the pieces must be butted together all around, as in Fig. 188. For angles above 25 deg. and to and including 35 deg. it is the standard practice of the Cleveland Frog & Crossing Co. to use miter joints in both the obtuse and acute corners; up to and including 25 deg. the rails forming the obtuse corners are bent; from 35 to 90 deg. the standard construction consists of continuous rails for one track, with arms abutted against them for the other track. Figures 186 and 189 show both butt and miter joints for 90-deg. angles. In long miter joints, as, for instance, in the acute corners of crossings at 45 deg. and less, the web should support the rail head to the extreme end of the joint or apex, as in the 40-deg. frog, Fig. 192. In order to carry the full web support in this manner the end of the rail is bent before the planing for the miter is begun. The engraving for the 20-deg. end frog, in the same figure, shows

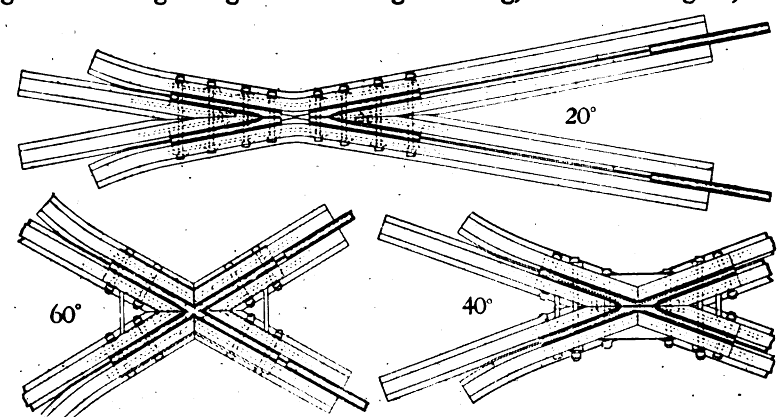


Fig. 192.—End Crossing Frogs.

how the web is carried out to the end of each piece when "main point and side point" construction is employed, as in ordinary single-pointed frogs.

Rolled iron or steel makes the strongest filling, but such must, of course, be used in separate pieces. The crossing frogs shown in Engraving *B*, Fig. 185 and in Fig. 189 are "cross filled" with rolled pieces halved together, so as to be continuous both ways. The filling of the 40-deg. end frog in Fig. 192 is in two pieces planed to fit together along the axis of the frog. The angle splices for crossing frogs should fit accurately and they should be heavy. In order to get the proper strength they should fill all the space between the head and flange of the rail. Engraving *G*, Fig. 188, and Figs. 186, 191, and 194 show examples of extra heavy angle splice construction. The type of stout splice shown sectionally in Figs. 186 and 194 affords the maximum sectional area for the thickness. Cast angle splices of this style —that is, extending flush with top of rail—as thick (horizontally) as 6 ins. have been used on the Grand Trunk Western Ry. The Cleveland Frog & Crossing Co. makes a heavy, solid cast steel angle bar which has the angle filled up and extended flush with top of rail, to form a triangular "easer block" outside the rail head, as shown in Fig. 193. Another stiffening device used a good deal is an angle brace, most frequently across acute corners, as shown in Fig. 192 and by Engraving *B*, Figs. 185 and 194. In

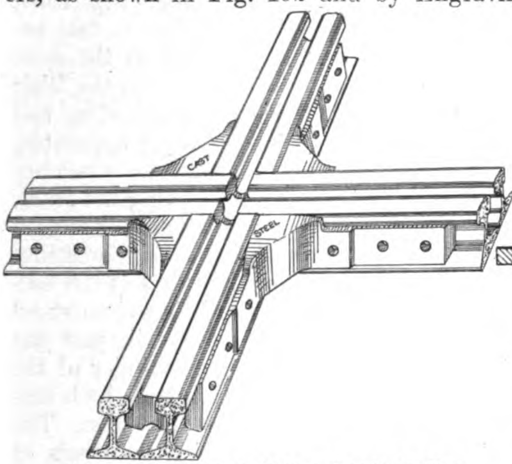


Fig. 193.—Easer Block Angle Splice.

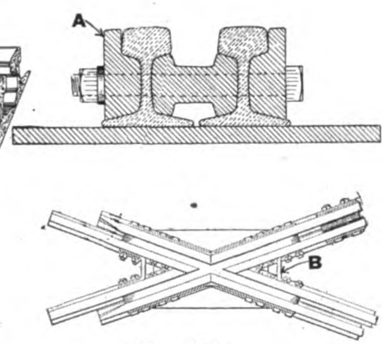


Fig. 194.

one style this brace consists of a heavy strap with the ends bent up against the arms of the frog, but on the 60-deg. frog shown in Fig. 192 the brace strap and angle splice are welded together, forming a solid A-shaped splice. In some instances these brace straps are placed farther out from the apex than in the positions shown, being sometimes as long as 18 ins. Aside from their general utility these corner braces are of good service to prevent bending of the crossing arms in handling during shipment. A bolt across the mouth of the frog (*R*, Fig. 188), with large beveled washers, is a good arrangement for securing the joints in the wing rails. The 40-deg. frog in Fig. 192 is shown with the large washers and two bolts, the latter passing through the webs of the point pieces. Still another stiffening arrangement is a base plate. In the largest practice plates are used only at the corners (*B*, Fig. 185), but in short-angle work continuous plates the full length of the crossing, under one of the tracks (Fig. 186), are used to some extent.

Movable-Point Frogs.—In small-angle crossings the guard rail of each middle frog (*HK*, Fig. 184) is sometimes set to shade the two points by about ⅛ in.; that is to say, the channels between *H* and *F'''* and *K* and *F'''*

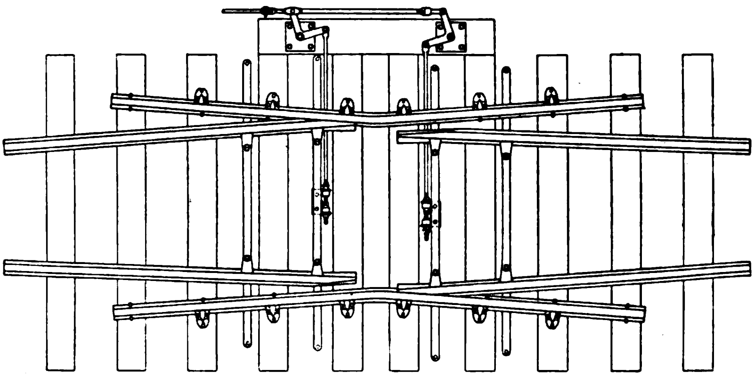


Fig. 195.—Movable-Point Frog.

are each made $\frac{1}{8}$ in. narrower than the channels between M and F''' and L and F'''. This arrangement affords some degree of security, but as the angle gets smaller it cannot insure safety. For crossing angles of less than 8 deg. the throats of two middle or double-pointed frogs would come so nearly opposite that it would be impossible to guard the points, in which case the point-rail crossing, otherwise known as the movable-point frog (Fig. 195), is used. It consists of two sets of short switch points placed face to face between two bent rails. They are moved in opposite directions at the same time, either by direct connection with a double-throwing stand on the Weir or Hasty idea (Figs. 163 and 164); or by a "T" or oppositely-acting bell cranks connecting with an ordinary stand or with interlocking apparatus, as appears in the figure; or by connecting both pairs of points to a balance bar, as in Fig. 190—the throwing of one set of points then moving the other. This arrangement also causes the points to operate automatically if trailed when wrongly set. The Weir automatic stand for movable point-rail crossings (Eng.C, Fig.185) has an adjustable spring working on a tail piece of the balance bar, on the principle of the action of the Weir automatic switch stand (Fig. 151). As soon as a trailing wheel throws the point rails past the half-way position the spring assists in throwing them the remainder of the distance and closes them tightly against the opposite stock rail, both sets of points being operated simultaneously and in opposite directions. The Elliot Frog & Switch Company's arrangement for throwing both sets of points at the same time, and which is also automatic, is shown by Engraving D, same figure. Figure 196 shows a stand for movable-point frogs used on the Pittsburg, Ft. Wayne & Chicago Ry. There is a parallel-throw ground lever turning a shaft and beveled pinion, the latter being engaged with a sector gear on the arm of a balanced lever connected to the two sets of points.

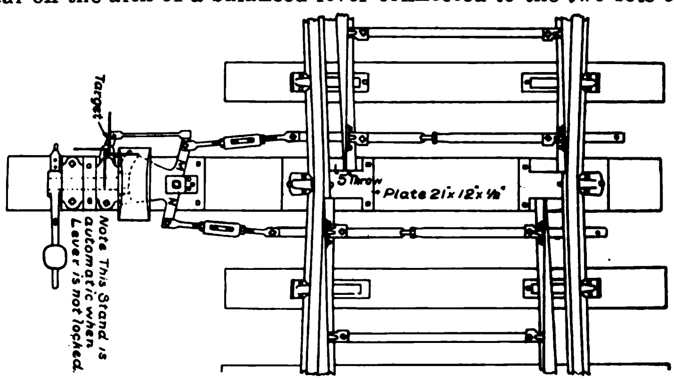


Fig. 196.—Stand for Movable-Point Frog, P., Ft. W. & C. Ry.

Other details in connection with the operation of the stand are made clear in the illustration. Another advantage in the use of the movable-point frog that is worthy of mention is that it provides a continuous-bearing rail; and another condition under which the use of the frog becomes desirable is where one or both of the tracks are on a curve.

All parts of a crossing should be made with rails of exactly the same form and size, and if the tracks be laid with rails of different weight the heavier or deeper section should be used throughout. If the difference in section be such that compromise splices are required in one of the tracks, a length of rail of the same section as that used in the crossing should connect with each frog, so as to remove from the proximity of the crossing any diversity of conditions in the joints. In loading or unloading crossings or sections of the same, as during shipment, considerable care is

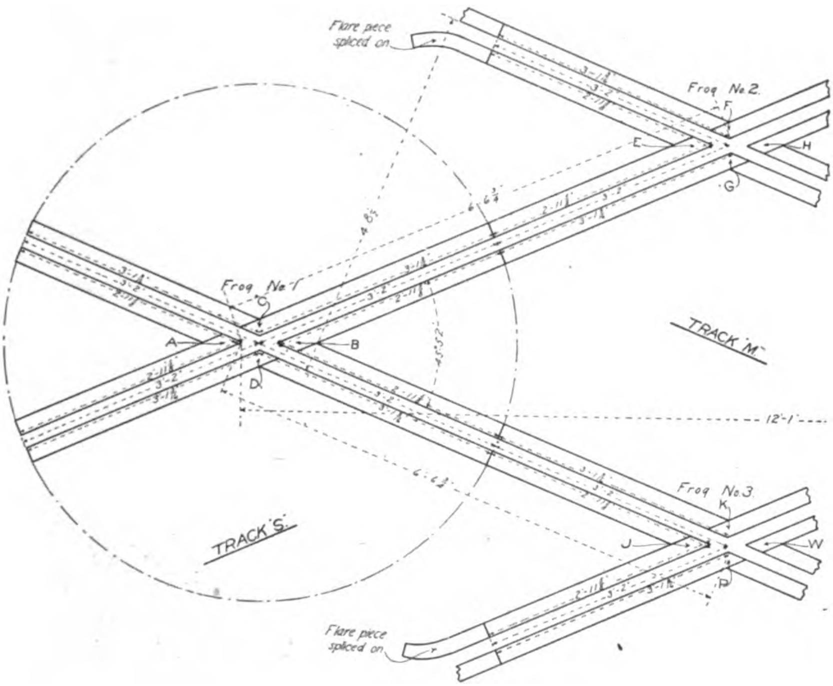


Fig. 197.—Mansfield Reversible and Interchangeable Crossing Frogs.

necessary to avoid knocking the legs out of line. At crossings on double track two joints in each track, not far from the crossing, in the direction from which the creeping takes place, should constantly be kept open, so that the running of the rails in the two tracks, in different directions, will not throw the crossing frogs into bad alignment.

Reversible and Interchangeable Crossing Frogs.—As all the parts of a double-rail crossing are not subject to wear from the traffic it would appear that if the frogs were made reversible or interchangeable the wear could be distributed more uniformly over the parts and thus increase the service of the frogs. Mr. M. W. Mansfield, engineer maintenance of way for the Indianapolis Union Ry., has put this idea into practice to some extent. The diagram of a set of frogs designed for the Erie R. R. according to Mr. Mansfield's plan is shown as Fig. 197. The two tracks cross each other at an angle of 45 deg. 52 min. and each frog is made symmetrical with respect to the point of intersection of the center lines of the filler blocks. All legs symmetrical with either axis of the frog have the same length, and these lengths are not arbitrary. Having the gage of the track and width of flangeway the angle of the crossing then determines the length of the legs. The flare of the guard rails is made by curved pieces spliced on, as shown. As both ends of each frog are the same, and all four frogs exactly alike, any or all of the frogs may be reversed in place, or any one will fit in the place of any other. The utility of the design for the purpose intended may, for example, be considered with reference to Frog. No. 2. Under traffic the wear upon this frog comes upon the points *H, F* and *E*; that is, wheels rolling along the track "S" pass over *E* and *F* and wheels rolling along track "M" pass over *H* and *F*. The part *F* is then subject to wear from the wheels on both tracks, while the part *G*, being on the guard rail, undergoes no wear at all. Now if the frog be reversed in the same position the guard rails change places with the running rails and the wear will come upon parts *H, G* and *E*, the part *G* then being subject to "double wear" and the part *F* relieved of wear. Thus by reversing the frog in its place all parts of the frog are brought into service and the service upon all of the parts is equalized, inasmuch as the parts in double wear are

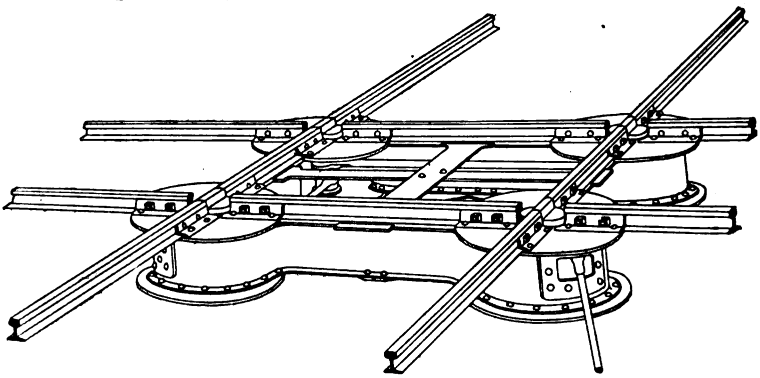


Fig. 198.—The Fontaine Crossing.

in service only half of the time. Or suppose that Frog No. 2 be interchanged with No. 1. The wearing parts then become *F, E* and *G*, corresponding to the parts *C, A* and *D* respectively, the part *E* (corresponding to part *A*) coming into double service. Next suppose the frog be interchanged with No. 6. The wearing parts then become *E, G* and *H*, corresponding to parts *J, P* and *W*, respectively, the part *G* (corresponding to part *P*) then coming into double service. By interchanging the frog with No. 4, not shown, the parts *F, H* and *G* become the wearing parts, with part *H* in double service. Thus by interchanging each frog with the frogs at all of the four corners of the crossing, each of the four points about the throat of the frog is in turn brought into double service and the wear upon all the parts of the frog is equalized.

With frogs of this kind in a crossing of two tracks one of which is much used and the other but little used, as, for instance, the crossing of a main track by a siding or branch line handling but a small amount of traffic, the economy of wear is equally, if not more, apparent. Suppose track "M" be a main track or a track much used and the track "S" a side-track or track but little used. It is evident that in a case of this kind the wear on frog No. 2 would come principally upon the parts *H* and *F*, while the part *E* would come but little into service; and on frog No. 1 the same applies to the parts *A* and *D* in the main track, and part *C* in the side-track. If now frogs No. 2 and 1 be reversed in place or interchanged, the parts *H* and *F* and *A* and *D* will be relieved of wear from the traffic in the main track and the parts *G* and *E* of frog No. 2 and *B* and *C* of frog No. 1 will come into main-line service. The life of the frog should therefore be practically doubled. Two sets of these frogs in service at the crossing of the Belt Ry. with the Cleveland division of the Cleveland, Cincinnati, Chicago & St. Louis Ry., in Indianapolis, Ind., after being reversed and changed four times, had given between two and three times the amount of service previously obtainable from frogs of ordinary pattern used in the same crossing. Interchangeable crossing frogs of the same design are also in service on the Chicago, Indianapolis & Louisville Ry.

Crossing Support.—Crossing ties should be long switch ties, placed diagonally to the two tracks rather than squarely across one of them, the preference being to place the ties at right angles to the longer diagonal of the crossing, and thus symmetrical to both tracks. In some situations, however, it is considered good practice to lay the ties at right angles to the line of heavier traffic. On a few roads ordinary ties are used, the ties of the two tracks being interlaid so as to come as nearly as may be at right angles in each track. Large sleepers placed longitudinally under the rails, halved together where they cross under the frogs (Fig. 191), are sometimes used, in place of ties. For square crossings the Buffalo & Susquehanna R. R. uses sleepers 12x16 ins. in size. Mr. Jerry Sullivan described, in the Railway Review for Apr. 9, 1892, a substantial foundation for crossings where the intersection angle is 90 deg. or nearly so. He excavates to a depth of 19 ins. under the rail base and lays 7x9-in.x9-ft. sawed ties side by side in the bottom of the trench, over a length of 9 ft. of track. On top of these, and crosswise, three pieces of 12x12-in.x9-ft. timber are laid, two being used as sleepers for the rails of one track and the other lying in the middle of the same track, all three pieces then acting as cross ties for the other track. The idea seems a good one and no doubt a further improvement would be had by using bed ties of 12 ft. length and two extra 12x12-in. timbers properly spaced outside the three, as per his arrangement.

The drainage of crossings is very important. Unless the ground under the crossing can be kept reasonably dry it cannot be expected to maintain the crossing in good surface. The best practice seems to favor the use of a good depth of broken stone ballast, with drain tile for foundations that are shut in, or from which the water cannot readily escape. A committee report to the Roadmasters' Association of America, in 1896, recommends a pit 4 ft. deep framed with timbers and filled with crushed rock, with a drain from the bottom of the pit. When tile is laid under track at a crossing the foundation should be excavated to slopes which will give drainage to the tile.

Continuous-Rail Devices.—As the angle between the two tracks approaches 90 deg. it becomes more difficult for crossing frogs to give satisfaction, owing to the open channel space lying more nearly square across the rails and allowing the wheels to drop. Numerous devices have been contrived and tested for overcoming this objectionable feature, but without any permanent success. The result of a noteworthy attempt at solving the difficulty is the Fontaine crossing (Fig. 198), tried some years ago on the Baltimore & Ohio; Vandalia; Pittsburg, Ft. Wayne & Chicago and other roads. It consisted of four vertical turrets connected together by heavy rods and enclosed within a strong frame of channel iron. At each corner there was a short piece of rail mounted upon a small turntable arrangement rotated by connection with an interlocking tower. It is said to have preserved a smooth riding crossing and to have shown durability to a marked degree, but the unavoidable accumulation of rust and grit caused revolving parts and locking bars to work so hard that their operation became unreliable. Four of these devices used in the crossing of the Chicago Terminal Transfer and the Chicago & Grand Trunk roads at 49th Street, in Chicago, from 1892 to 1897 were finally condemned and sold for scrap. During the five years they were once rebuilt at an expense of about $800, and they were a source of annoyance the whole time. It required the services of an extra man practically day and night to keep the crossings oiled and in proper adjustment. Every little while one of the revolving posts would break, requiring one of the tracks to be abandoned until repairs were made. The reason for relating this much of experience with the Fontaine crossing is that it was an exceptionally well built device, and the information concerning the same may be of value to persons inclined to experiment with crossings got up on the same idea, which seems to be a favorite one with inventors.

Gantlet Tracks.—It sometimes becomes necessary for the trains of two (usually parallel) tracks to traverse the same space for a short distance where there is not room enough for two tracks at clearing distance apart: such, for instance, as the passing of a double-track road through a narrow street; or over a bridge or through a tunnel built for single track. In such cases no switch is needed, as the rails of both tracks may be laid side by side on the same ties, as near each other as may be convenient—say 8 ins. apart. The crossing of the two inner rails is made by ordinary frogs, as shown in Fig. 199. This arrangement of two tracks on the same ties is known as a "gantlet track." The weighing track over track scales is usually gantleted with another, so that cars which are not to be weighed may pass without bringing load upon the scales.

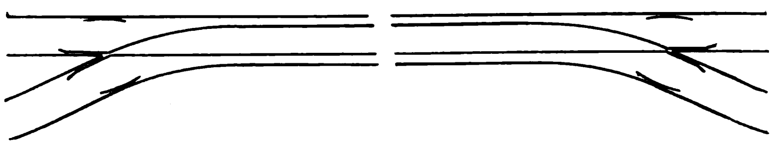


Fig. 199.—Gantlet Track.

An interesting application of gantlet tracks was put into temporary service in the Musconetcong tunnel of the Lehigh Valley R. R. in 1899 while a portion of the same was being lined. There was a double track through the tunnel, and during hours when the work of lining was being carried on it was found desirable to divert all traffic to the center of the tunnel, so as to get room at the sides for tram cars which were used to carry out the excavated rock. A rail was laid outside each main track and used with the outer rail of the latter for a tram track of 2 ft. gage. As the traffic was heavy (an engine or train passing through the tunnel every 10 minutes, on the average) it was found expedient to use the regular tracks at such times as the tunnel work did not interfere. No work was done nights and Sundays, and at other times the work did not obstruct the regular tracks all of the while. To make room for the side supports of the arch centering the main tracks were thrown in to 11½ ft. centers, as shown in Fig. 199A. The arrangement for single-track operation consisted in laying two rails in the space between the tracks, to gage with the inner rails of the main tracks, thus forming a second track alongside each main track. The outside of the inner rail of the main track in this case was the gage side for the "second" track, and the two so-called "second" tracks were gantleted together in the space between the two main tracks. In other words, for east-bound movements there were two tracks on three rails, or two tracks using one rail in common; for west-bound movements there was a like arrangement independent of the other; and the inner of the two tracks for movements in each direction were gantleted. The illustration shows the arrangement of the ties laid for the support of the extra rails, including the rails of the tram tracks, laid outside the main tracks for running the excavated rock out of the tunnel while traffic was being operated over the gantlet tracks. The rails for the gantlet tracks were laid on the ends of the ties of the two main tracks, but too near the ends to permit them to be securely spiked. In order to hold these rails to gage it was necessary to interlay ties between the ends of the ties of the main tracks, as shown. As the ties in the main tracks did not everywhere stand opposite each other, it was not practicable to lay ties for the gantlet track between each pair of ties in the main tracks. It was feasible, however, to lay 10 or 12 ties per rail length for holding the gantlet tracks to gage.

The switch connections for the gantlet operation are shown in Fig. 171A. For west-bound main-track movements the rails A and B were used, while for west-bound movements through the gantlet the rails B and C were used. For east-bound main-track movements the rails X and Y were used, and for east-bound movements through the gantlet the rails Y and Z were used. The switching of trains from each main track to the gantlet was by an ordinary point switch operated from an interlocking tower and telegraph office outside and near one end of the tunnel. All train movements over the gantlet were controlled from towers at either end of the tunnel. The turnout lead from each main track into the gantlet was a 5-deg. curve, and as the arrangement was only temporary there was no frog

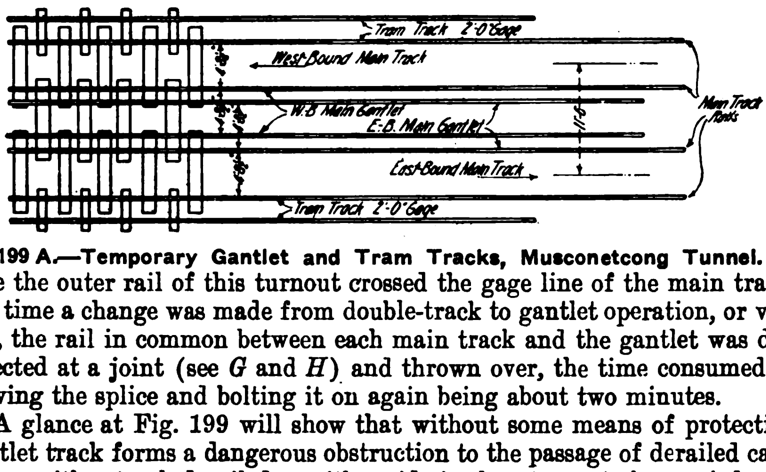


Fig. 199 A.—Temporary Gantlet and Tram Tracks, Musconetcong Tunnel.

where the outer rail of this turnout crossed the gage line of the main track. Each time a change was made from double-track to gantlet operation, or vice versa, the rail in common between each main track and the gantlet was disconnected at a joint (see G and H) and thrown over, the time consumed in removing the splice and bolting it on again being about two minutes.

A glance at Fig. 199 will show that without some means of protection a gantlet track forms a dangerous obstruction to the passage of derailed cars. A car on either track derailed on either side is almost sure to be carried over and break the train, after passing the frog at one end or the other of the gantlet. To avoid trouble of this kind as far as possible a bridge guard, consisting of two rails gradually drawn in to meet in the center of the track, is laid at the heel of the trailing frog in each track.

How to Avoid Switches on Curves.—The elements of danger always present with switches leading from the outside of curved track make it desirable, as heretofore stated, to avoid such arrangements wherever the situation will permit. In some instances, however, it is found to be necessary to lead a side-track or branch line from the outside of a sharp curve. Under such a condition the frog must be placed on the curve, but by going to some expense the switch may be placed back on straight line and the lead gantleted around the curve to the frog placed at the desired point of departure. In one application of the arrangement which I have seen a side-track branches from a sharp curve the P. C. of which comes at the end of a swing bridge. For lack of room the opportunity for laying a switch and desirable lead on that side of the bridge was otherwise not good, and so to solve the difficulty the switch was put in on tangent, in advance of the bridge, and the lead gantleted across the bridge to the frog leading out of the curve just beyond.

Gantlet leads are in use at several places on the Denver & Rio Grande R. R., for the purpose here in view, and the operation of the same is quite satisfactory. An illustration of a layout of the kind is shown in Fig. 168, some pages back. The particular turnout is from third-rail track (4 ft. 8½-in. and 3-ft. gages) at Hecla Junction, a few miles west of Salida, Colo., where a narrow-gage branch line leaves a 7° 30′ curve in the main track and extends to some iron ore mines at Calumet. (It may prove interesting to state that the grades on this branch line reach a maximum of 7½ per cent.) In the illustration it will be noticed that the headblock of the stub switch is located on straight track 57 ft. from the point of curve. In a distance of 30 ft. from the headblock the lead rails of the narrow-gage turnout separate from the rails of the main-line narrow-gage track a distance of 1 ft., from which point onward they are carried the same distance apart. The throw of the switch in this case is 5 ins. The point of frog is 488 ft. from the headblock, the rails for the narrow-gage tracks being gantleted 1 ft. apart to a point within 36 ft. of the point of frog, where the curvature of the long lead is reversed to turn out through the No. 10 frog. The ties in the gantleted lead are of ordinary length, or 8 ft. long.

78. Slip Switches.—At a crossing of two tracks traffic may be switched from one track to the other by a set of switch points in each track, the two facing in opposite directions and connected by a curve—all contained between the two end frogs of the crossing. Such an arrangement is very convenient for crossover work, or where economy of space is necessary. It is called a "slip switch" or "combination crossing." No frogs are used in passing through it from one track to the other. These switches are used mostly in yards for connecting a leader with the parallel tracks which it crosses. For this purpose it accomplishes not only a great saving of track room longitudinally of the yard, as compared with a series of crossovers with frogs of the same angle as are used in the leader, but it also affords a much better alignment for a train movement across all or a number of the parallel tracks. Consider, for illustration, six parallel straight tracks at 13 ft. centers. A series of crossovers using No. 6 frogs, with headblocks 10 ft. apart on the intermediate tracks, will extend about 725 ft. lengthwise the yard; and a train moved from Track No. 1 to Track No. 6 will pass through ten turnouts and meet with nine reversals of curvature. A leader across the same yard, with No. 6 frogs at the crossings and slip switches connecting with all the intermediate tracks will extend only about 445 ft. in longitudinal yard space, thus saving 280 ft. in length of yard; and a train moved from the first to the sixth track will traverse only two turnouts and one reversal of curvature.

A slip switch is single or double according as it gives access from either track to the other in one or both directions. It is evident that with the "single slip" (Fig. 200) the movement of trains in one direction on each track is trailing to the slip points, in which case the train must back, in passing to the other track. With the "double slip" (Fig. 201) a train may pull straight ahead from one track to the other when approaching the crossing in either direction on either track, slip-switch connection being made across both obtuse angles of the crossing. As already stated, two kinds of middle frogs (rigid and movable-point) are used at crossings, and of course either may be used in connection with slip switches, whether the latter be single or double. With crossing frogs of the larger angles, however, the movable-point frog permits the laying of a more suitable curve, the inside guard rails of the rigid frogs being somewhat in the way, when such are used.

Figure 202 shows a device employed by the Morden Frog & Crossing

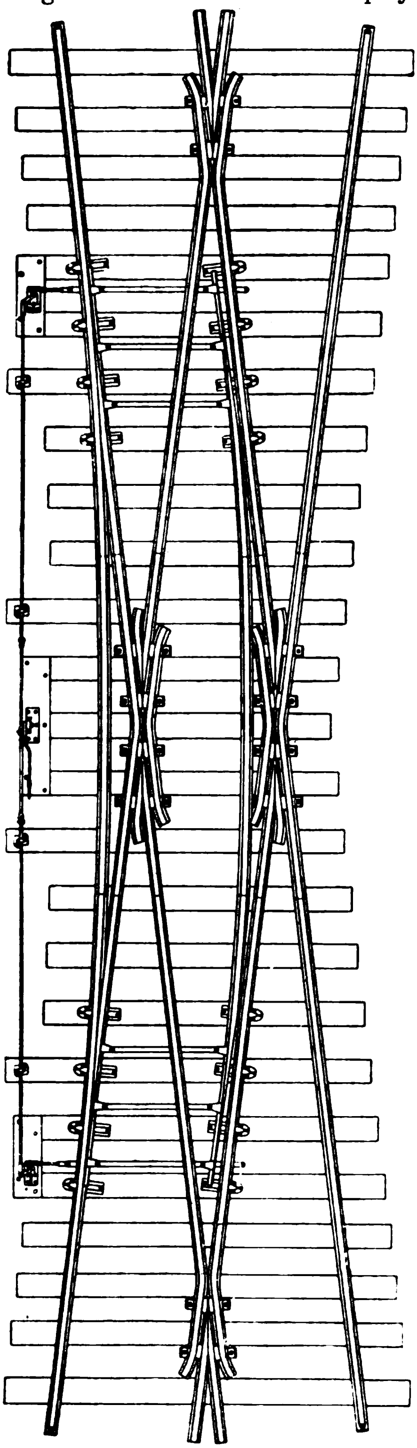


Fig. 200.—Single Slip Switch with Rigid Middle Frogs.

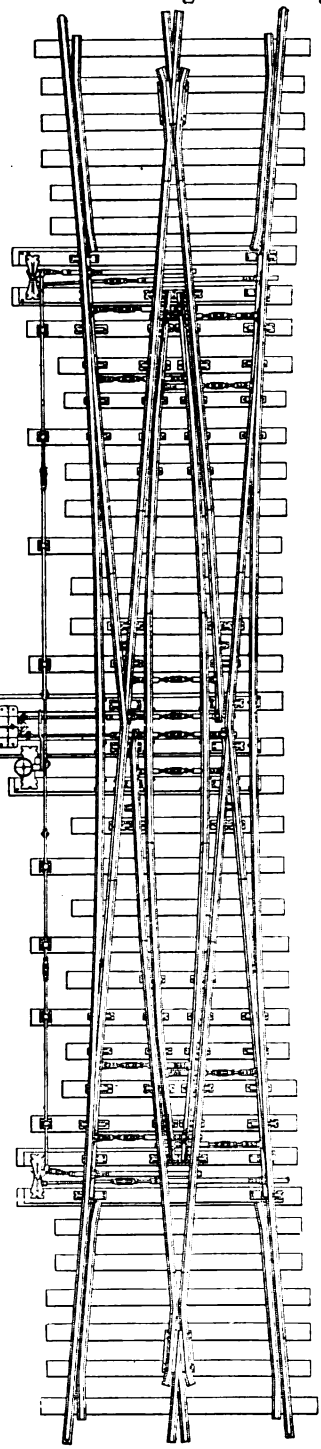


Fig. 201.—Double Slip Switch with Movable-Point Frog.

Works to secure the outer rail of the slip curve, where there are rigid middle frogs, by bolting it to the guard wing of the frog. The connection is by means of channel or U-bars, as shown in the sectional view *A-B*. The idea is to assure that all parts of the combination will be laid in exactly their proper relative positions and secure them against being changed from such. In the yard tracks of the Southern Union Station (Boston Terminal Co.) in Boston a similar device is used at the heel joint of each point rail in slip switches, including the point rails for the movable-point frogs. It consists of a channel bar 10 ins. long and 3 ins. deep with two bolt holes in each flange—one for a bolt each side of the joint. This channel is bolted against the splice bar on one side and against the web of the stock rail on the other side. The rails are of 100-lb. section, the slip points being 13 ft. long and the movable points of the middle frogs 10 ft. 10 ins. long, and in order to obtain free working of the same it is found necessary to leave the heel splices slightly loose. In order to do this without permitting slack nuts the splice bars are tightened up against 1-in. pipe thimbles or spools on two of the bolts just long enough to prevent the splice bars from pinching the rails when the bolts are tightened. In order to receive this spool the bolt holes in the rails are reamed out to a diameter of 1$\frac{3}{8}$ ins. Another device used for the same purpose as the two channel fastenings just mentioned is a cast filling block of short length through-bolted with the webs of the rails.

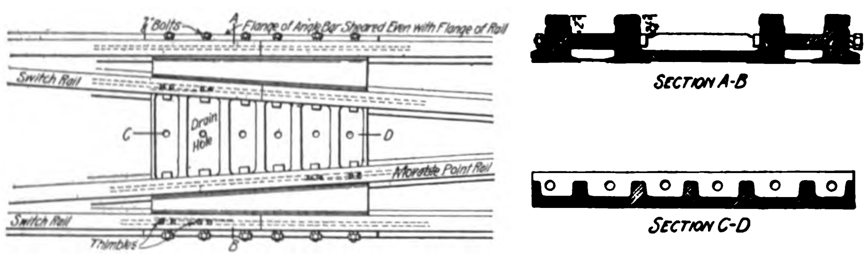


Fig. 201 A.—Anti-Creeping Heel Castings for Movable-Point Frogs and Slip Switches.

The angle or number by which a slip switch is designated is the angle or number of the crossing in which it is located. There is a limit to the room available for a slip switch as the number of the crossing frog gets smaller. With frogs lower than No. 6 the curve that must be laid to connect the heels of the two sets of switch points becomes so sharp as to be impracticable of operation. A No. 6 slip is about the lower limit for switch engines; and No. 8 for passenger trains, when used in connection with a movable point frog; Number 15 is about the upper limit. As usually laid, the point rails of slip switches are evenly matched, but the Weir Frog Co. uses long and short points, as is shown in Fig. 201. The longer point is placed on the inner side of the slip curve, for the purpose of effecting an increase of gage in the curve without having to increase it at the bend of the stock rail or introduce a kink in the inner rail of the curve after it leaves the point rail. The manner in which this is accomplished becomes entirely clear if it is considered that the long point extends past, and the bend in the stock rail lies beyond, the real point of switch. If, therefore, the gage be correct at the bend of the stock rail, it must be somewhat wider at the point of switch. It will be further noticed that this slip switch has long tie plates or steel bridle plates, 8 ins. wide by ½ in. thick, extending under the slip point and stock rails and continuous beyond the T-crank housings, and also under the movable frog points and bases of the two stands operating the slip points and frog points. This arrangement is intended to decrease the tendency to lost motion or change of relative position between operating and moving parts.

The standard No. 8 double slip switch of the Chicago & Western Indiana R. R., adapted for interlocking, is curved through the slip 11 deg. 22 min., and the actual distance between the frog points at the ends of the crossing "diamond" is 76 ft. The length of the slip switch points is 18 ft. and the slip curve begins at the heel of the planing, which runs out 7 ft. 9 ins. from the point end. The throw is 4 ins. The gage of the track on the slip curve is 4 ft. 8¾ ins. The movable frog points are 8 ft. 8⅜ ins. long and the throw 4 ins. The slip switch points have a reinforcing bar ⅜ in. x 2½ ins. x 10 ft. long on the gage side and another ¼ in. x 2½ ins. x 9 ft. 2 ins. long on the back side, ending 10 ins. in rear of the switch point. The movable frog points have reinforcing bars ⅜ in. x 2½ ins. in section on both sides, that on the gage side being 4 ft. long and that on the back side being 3 ft. 2 ins. long, ending 10 ins. in rear of the point. The rail is of 80-lb. section, and the slip and crossing points and connecting rails are well supported upon tie plates and securely braced. Both rail braces and braced tie plates are used, the latter being formed by splitting the end of the plate along the center line and turning up half of the end for a stop, the other half, which remains flat, being punched for the outside spike. At the points where the thrust of the switch rails is received by the main

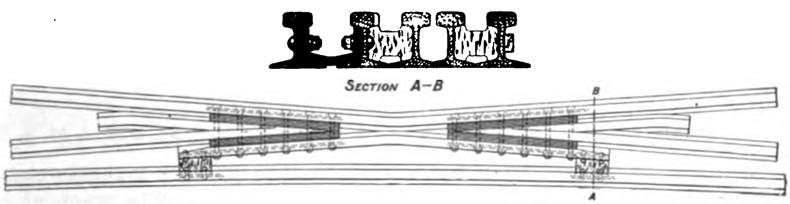


Fig. 202.

rails, through plates 6 ins. wide and ½ in. thick are used, with rail braces. Both the movable frog points and the slip switch rails heel at a common point, and as a means of securely splicing them, as well as to avert derangement of the interlocking and other troubles from creeping rails, the joints are bolted through and through with heavy cast filler blocks of anti-creeping pattern, the details of which are shown in Fig. 201A. The castings at each heeling point are three in number and 33 ins. long. The castings are made to fit the rails snugly, and to allow free movement of the point rails the casting is tapered off at the point where movement is necessary. To provide for tightly bolting up the splice bars the bolts have pipe thimbles which take the pressure between the outer splice bar and the casting, thus permitting the necessary lateral movement for the switch rail, which, being short, would either work very stiff or fail to throw at all if room was not provided in this manner.

There are various throwing arrangements for slip switches. The simplest is, of course, to place a switch stand opposite each end of the slip and another opposite the center to throw the movable-point frog, in case such is used. This arrangement for throwing each set of points independently of the others is in vogue to some extent, ground levers being the type of stand usually employed, but it makes a good deal of work for the switchmen. Except in interlocking, the points of slip switches are usually operated by one switch stand placed opposite the middle of the crossing. In double slips all four sets of points have connection with the same stand and are operated together. In most instances connection is made from stand to points by means of "tumbling rods" (pipe lines) and bell or T-cranks.

To keep the adjustment of the tumbling rod correct it is necessary to prevent relative movement of the end and middle ties, and this is sometimes done by spiking a plank (usually 2x6 ins.) to the tops of the ties just inside the tumbling rod, or by a long iron plate running the entire length of the slip beneath the tumbling rod and spiked to the ties. The Elliot throwing arrangement consists of a rocker shaft extending the length of the slip in the usual place, outside the track, with suitable connection to the points and to an operating stand midway of the crossing. The intention of this form of connection is to eliminate the effect of expansion and contraction as a disturbing influence on the switch adjustments.

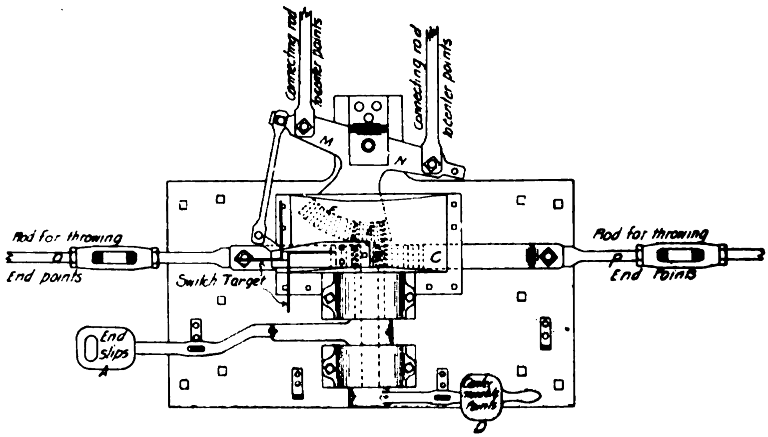


Fig. 203.—Double Stand for Slip Points and Movable-Point Frog, L. S. & M. S. Ry.

Where movable-point frogs are used with slip switches separate stands are usually employed to operate each, one being placed within reach of the other; that is, one stand operates the frog points and another the slip points, as in Fig. 201. As the frog points cannot properly be used while the slip is thrown for service (not at all in case of double slips) it matters not what their position may be in such event. It is also clear that, with the slip points set in their normal position, only one stand at a time need be thrown for any train movement whatsoever about the crossing. With the slip points open to the crossing tracks, however, it might be necessary to throw both stands in order to permit a movement over the crossing, and some think that both of these operations should be controlled by the same stand. By a mistake on the part of the switchman in throwing the wrong stand, or in not throwing both, or even in throwing the lever to the wrong position in the case of a single stand, it is possible, evidently, to run the wheels against a pair of points wrongly set for the intended movement. When both frog and slip points are thrown together six sets of points must be operated by one stand, in the case of double slips. While such must be a hard-throwing arrangement, still its use avoids the possibility of some mistakes which might result from confusion in the use of two stands.

A single stand for operating both middle and end points must be a triple or three-throw device, one movement being requisite for setting the slip points and two movements for setting the movable-frog points. The Elliot arrangement (Fig. 104A) for this purpose consists of two rocker-shafts, each connected to a pair of points at both ends of the slip and to a pair of movable-frog points, but working reversely; the rocker-shafts are operated by a Hasty stand (Fig. 164). When the switch stand lever is in the middle notch, as shown, it gives both slips; but in throwing the lever from the middle to either of the extreme notches, only one pair of points in each slip is moved; and this pair gives that track for which the frog points are set. The other pair of points in each slip remains unchanged from the position held when the lever is in the middle notch. With the lever in either extreme notch, then, the situation is just this: one of the tracks through the crossing is clear, while in the other track through the crossing a pair of points in each slip is set to give the slip. A train attempting to pass through the crossing in either direction on this latter track would, therefore, be turned into one of the slips and would force the points at the far end of the same, but could not run against the center or movable frog points. It is therefore impossible for a switchman to make a mistake on the center points and they cannot be run against in any event. In throwing the lever from one extreme notch to the other extreme notch all slip and center points change position and way is given over the other track through the crossing. When desired, the switch points are connected to the shafts with spring connecting rods, so that the split rails cannot be damaged in event the switch is forced when wrongly set for a trailing train, as just explained.

The Cleveland Frog & Crossing Co. at one time produced a three-throw stand operating directly on a lever pivoted at the center, for throwing the movable center frog points, and on a large bell crank for throwing the switches at both ends of the slip. Some of these stands were used on the Vandalia Line (Terre Haute & Indianapolis R. R.), and although the working principle was evidently correct, the stands were made too light for the service. The double stand shown as Fig. 203 was then designed as a substitute. It combines a compact arrangement of two handles, one for throwing the center or movable-frog points and the other for throwing the end or slip points. The handle *A*, lettered as shown, to prevent mistake, turns the plain pinion *B*, which actuates the rack bar *C* to the left or right. The rack bar works underneath the pinion and is connected by turnbuckles to the rods *O* and *P*, for throwing the end points. Handle *D* for throwing the center points turns the beveled pinion *E* by a shaft passing within the shaft to which pinion *B* is keyed. Pinion *E* moves the sector gear *F*, swinging underneath, *F* being one piece with the arms *M* and *N*, which are connected with the center points by rods. The bottom plate of the stand is of iron, 1 in. thick, and the stand weighs 300 lbs. The sector gear *F* and the rack bar *C* are made of cast steel. The switch target, being in this case a low one, is revolved by a rod connecting with the arm *M*. The gears (shown in broken lines) are enclosed under a cast iron box, as a means of protection against snow and dirt. This type of stand is in service on the Lake Shore & Michigan Southern Ry. The Chicago Junction Ry. has in use for slip switches a stand performing similar functions, on which the two levers are interlocked in such a way that the movable frog points cannot be set contrary to the position of the slip points. This stand was designed and made by the Ajax Forge Co.

79. Y-Tracks.—A "Y" consists of three tracks called "legs" arranged in the form of a triangle, each track connecting with the other two by switches. When locomotives or cars are run around it they come back to the first track turned about from the way they started. If not too long, and land is cheap, it is less expensive than a turntable and more convenient, especially where there are cars to be turned with the locomotives. In order to save room, the legs of a Y are usually made curved track their whole length. Where the main track is used for one leg it is usually straight and the other two legs curved. The "Y" enclosing the least possible ground is one having the three legs equally curved and of as sharp degree of curvature as the rolling stock will stand with guard rails. The three switch points of such a "Y" lie at the vertices of an equilateral triangle having sides the same length as the radius of the curves. That is to say, if each of the three legs be 20-deg. curves, the equilateral triangle whose vertices lie at the three points of switch has sides 287.9 ft. in length, or the same length as the radius of the curves. The length of track required beyond the switch points of the "Y" depends on how many cars are to be turned with the locomotive. On a "Y" of the Peoria & Pekin Union Ry., at Peoria, Ill., 12 to 15 passenger trains are turned daily, without uncoupling from the locomotives. Before this means of turning was put into service combination and certain other cars, which it was desired to run with the same end always forward, had to be turned singly on a turntable, consuming a good deal of time.

A turnout connecting two tracks at a crossing, with switches outside the end frogs of the crossing, is known as a "transfer"; the same term is also applied to a connecting track between two roads which cross on separated grades. Wherever a transfer track is maintained between two roads at a crossing it requires only an additional transfer to make a "Y." Unless the crossing is at a large angle, however, say between 70 and 90 deg., the room required for this second connection (on desirable curvature) is rather excessive. If the two tracks cross at right angles, or nearly so, there is opportunity for putting in a "Y" by leading two turnouts from one of the tracks to the other in opposite directions from a three-throw switch.

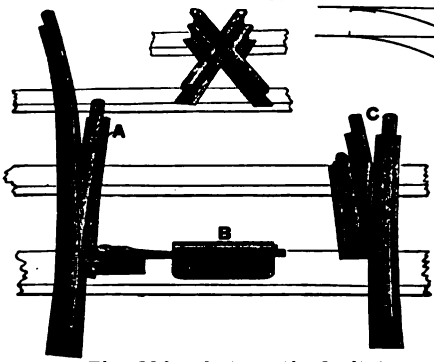


Fig. 204.—Automatic Switch.

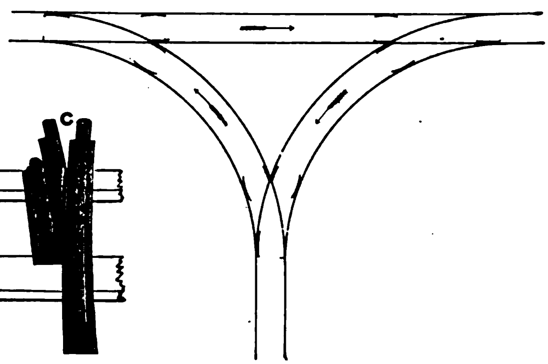


Fig. 205.

For light steam or dummy roads, electric roads, or wherever the rolling stock can use heavy curves, automatic switches can be arranged at the three turnout points of a "Y" to be thrown by the locomotive itself. In Fig. 204 there is shown an automatic switch, and in Fig. 205, a "Y" laid with these switches. The point rail *A* is held by a housed spring *B* which closes it after each wheel flange passes by, the action being similar to that of the hinge rail of a spring rail frog. The device *C*, placed opposite the point rail, is called a "mate;" its true point (the intersection of the two gage lines) is placed about opposite the end of the point rail, or slightly in rear of it. The locomotive trails around the "Y" in the direction of the arrow points, and the operation of the switches is apparent.

80. Turntable and Drawbridge Joints.—Where but one track extends both ways from a turntable, considerable trouble is often experienced with the joints at the ends of the table. A common arrangement for latching turntables is a flat bar or bolt working in guides and fitting between stop lugs or into a socket, being usually operated by a lever; and another arrangement extensively used is a hinged bar thrown over into a cast-iron jaw or between stop lugs. In either case the parts of the latch are usually attached to the track ties, both on the turntable and on the abutment or pit wall. Careless hostlers are much in the habit of bringing the table to rest by shoving out or dropping the latch bar, instead of first stopping the table. Unless firmly held by masonry, or braced by heavy coping timbers extending around the pit, the abutment track is in this way thrown out of line and at the other end of the turntable there is formed an ugly lip which, in the dark, is likely to be unnoticed and the cause of derailing locomotives when moving off the table. It is in this way that serious damage or inconvenience is sometimes charged to defective track when the real cause is bad discipline among employees not supposed to be responsible for the condition of the track. This trouble can be avoided by latching the table to the masonry of the pit wall instead of to the abutment track; or by using a latch which cannot be put into place for locking the table until the table has been brought to rest in the right position.

One device of the type first described consists of vertical rollers pressed against the pit wall by an adjustable spring and locking into curved recesses in castings built into the pit wall. If the table is swinging too hard when the latch springs, the lock will roll out and permit the table to pass on by, thus avoiding sudden shock. A device of the other type mentioned, which is used a good deal, is a sliding cross bar with "T" ends fitting between the webs of the rails. It lies in the track, at the end of the turntable, and when the turntable has been swung into line with the fixed track this bar is shoved with the foot or by a lever to place the "T" ends across the joints in the rails. A wide flat bar is sometimes used in place of the double T-iron. A still simpler arrangement, employed on some roads, is a piece of plank used in the same way. The length of the plank corresponds to the gage of the rails, web to web. When the tracks have been brought even the plank is slid across the joints; that is, the plank lies crosswise in the track, half on the table and half on the abutment. The simplest arrangement of all is to dispense with latching devices entirely, which requires that the table must be held in place or watched when an engine is passing on or off, until the first pair of wheels has passed the joint, the rigidity of the wheel base being sufficient to hold the table in line after that. The practice of dispensing with latches is extensively in vogue. It saves trackmen a good deal of trouble, and seems to be satisfactory from every other standpoint. To prevent the rails from cutting into the ties at the ends of the table and into the timbers on the pit walls they are sometimes supported at these points on steel plates or cast iron chairs.

End Rails for Drawbridges.—A common arrangement for the rails at the ends of drawbridges is a butt joint, the rails being seated in grooved chairs or on wrought plates with riveted lugs for lateral guards, placed on solid bearings on the abutment side. The bridge rails are movable, being usually held together by switch rods and guarded laterally by the backs of parallel angle irons bolted to the ties. Some sort of lifting device is provided to lift the rails out of the seats when the bridge is about to be turned. In addition to the bridge lock and the end seats a knuckled strut between the webs of the rails is sometimes used to hold the stub ends securely in line at the joints. Any misadjustment of the end bearings of the bridge permits some springing in the ends of the rails, and, owing to temperature changes, wide open joints cannot be avoided at all times; so that, sooner or later, heavy pounding is liable to arise. One way of obviating trouble of this kind is by a "carrier rail" joint (Fig. 206). A short piece of rail, *A-B*, is bolted to the outside of each lift rail on the bridge, so that it drops down just outside the abutment rail when the bridge is closed. The ends of this short piece of rail are sloped off, "easer" fashion, to lift the outside flange of badly worn tires, and the wheel is carried over the joint without shock. With this provision it is not necessary to maintain a close joint in the rails at the ends of the bridge, and hence trouble from the expansion of the rails in hot weather can be avoided to a considerable extent. One feature of the butt joint or stub end which is counted for safety is that, with expansion or creeping of the rails there is no tendency for the rails to lip at the bridge joint.

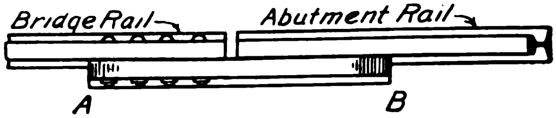


Fig. 206.—Drawbridge Joint.

Another type of drawbridge joint, widely considered the most satisfactory, is the split or skew joint, less frequently called a miter joint. Such joints are made 10 to 24 ins. long, the two sets of rails, for the fixed track and the movable span, overlapping on solid supports resting upon the abutment or wall timber. On double track the lap of the joints should be trailing to the train movements. In order to swing the bridge one set of rails, usually that on the bridge, must be lifted above the other. To maintain the gage of the movable rails they are held together by switch rods. The lifting mechanism commonly in use is a cam acting on the rail base, operated by a lever attached to a cam shaft at each end of the bridge or by a single lever at the middle of the bridge, connected with the two end cam shafts by throw rods. The movable rails are held between beveled guard blocks, so as to drop into proper alignment. To show some of the details of a joint of this type illustrations (Figs. 207-210) are presented of the joints of a plate-girder swing bridge on the Chicago, Burlington & Quincy Ry. at Ottawa, Ill. It will be noticed that the rails are lifted by a cam arrangement of the simplest form. The cams are attached to a shaft extending across the track underneath the rails, which shaft is turned by a lever thrown to the position indicated by the dotted lines when the rails are raised (Fig. 208). It will be noticed also (Fig. 209) that the webs of the rails where they are bent at their ends to form the skew joint are retained,

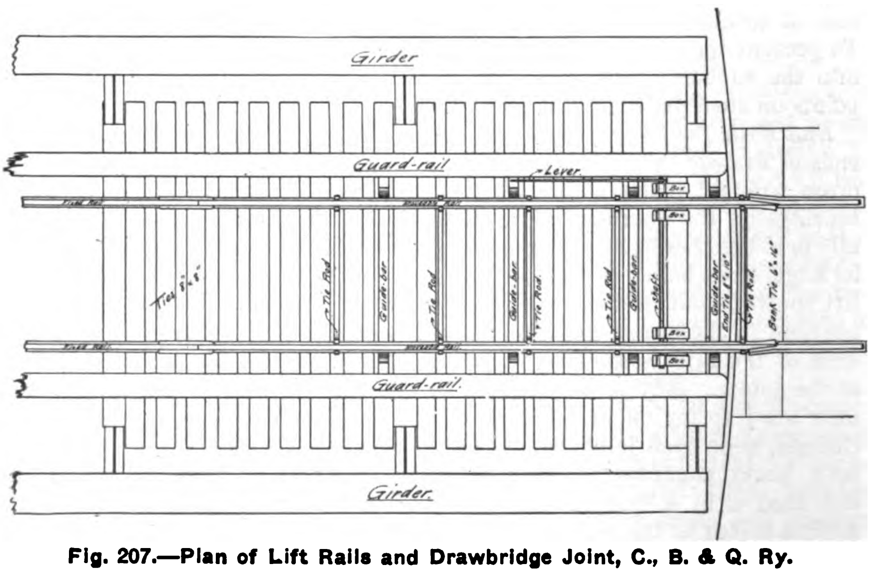


Fig. 207.—Plan of Lift Rails and Drawbridge Joint, C., B. & Q. Ry.

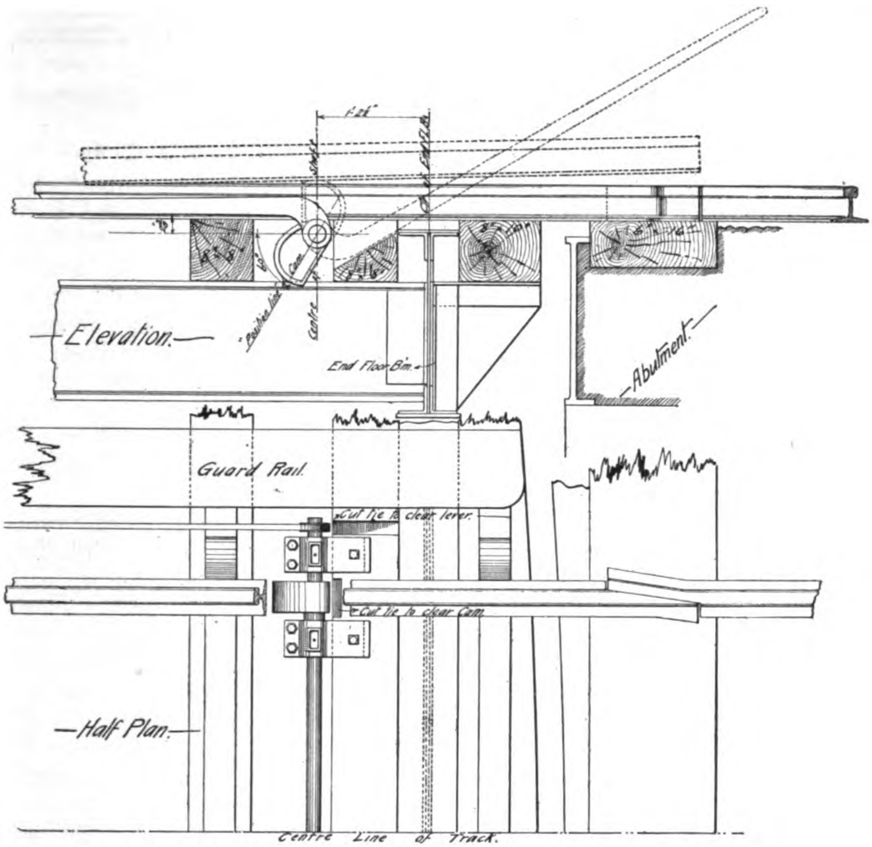


Fig. 208.—Details of Rail Lift for Drawbridge Joint, C., B. & Q. Ry.

thus very much strengthening the support for the rail head. The details of the hinge splice at the heel of each movable rail are shown in Fig. 210. The angle bars are bent in the middle enough to turn up ½ in. in 16 ins. The top is then planed down in line with the other half of the bar, so as to fit snugly under the head of the rail in its lowered position. The bottom flange of the splice bar is cut away for 8½ ins. back from the end. The bolt hole, in the rail, nearest the joint is reamed to 1 in. diam., and the second hole is slotted out to $1x1^3/_{16}$ in., as shown. Other details are made sufficiently clear in the illustrations.

To overcome the difficulty with creeping rails at the ends of drawbridges it is customary to place expansion joints in the track a short distance from the bridge. One form of joint designed for use in such cases is shown as Fig. 211. A pair of disconnected switch points is placed be-

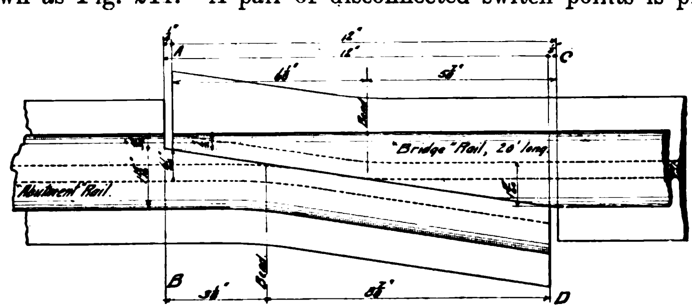


Fig. 209.—Details of Skew Joint for Drawbridge, C., B. & Q. Ry.

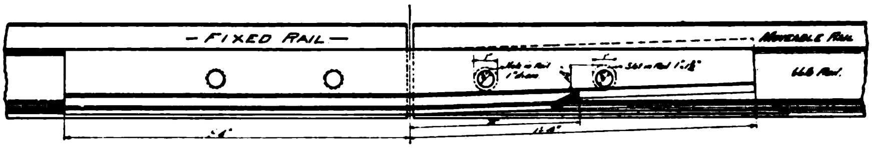


Fig. 210.—Hinge Splice for Drawbridge Lift Rails, C., B. & Q. Ry.

tween two stock rails and held tightly to place by a set of three spring clamps on each point rail. The spring clamp is adjustable and bears against the web of the point rail by the friction roller *F*, thus permitting free longitudinal movement. By setting the device with the gage a trifle wide on the start considerable expansion or creeping of the rails can be taken care of before the gage becomes too tight for safety. The arrangement can be improved upon, however, by separating the point rails on the two sides some distance instead of placing them opposite. This change would permit a guard rail to be laid opposite each split point to keep wheel flanges from contact with it. On double track the split rails would, of course, be laid trailing to the traffic, but in any event a guard rail protecting the split rail its whole length would be approvable.

81. Yard Tracks.—The matter of arranging tracks in freight yards so as to minimize the amount of switching and the amount of interference between working crews, to the end that trains may be made up with the least amount of handling and with greatest dispatch, is of great importance; yet most of the large freight yards throughout the country have been enlarged from smaller ones without keeping with any definite plan. While as to details experienced yardmen might not entirely agree as to the best arrangement of tracks for any given yard, there are, nevertheless, certain features of yard design which, in the main, meet with general approval. Of course the locality has much to do with the way a yard should be arranged, and the question of making most use of available ground is often the matter of weightiest consideration. A yard entirely satisfactory in one case might not meet the requirements of some other place where the conditions peculiar to the traffic may have special demands. The arrangement of tracks in one yard may not be a satisfactory pattern for another. By way of illustration, the yard may be at a terminal point, where its function is to distribute the traffic going to various industrial establishments, factories, grain elevators, steamship wharves, coal docks, stock yards, freight stations, team tracks etc., and to assemble into trains the outbound shipments originating at or delivered from such sources; or the business of the yard may be partly or principally that of handling the interchange of traffic with other roads. The handling of traffic between the yards of several railways

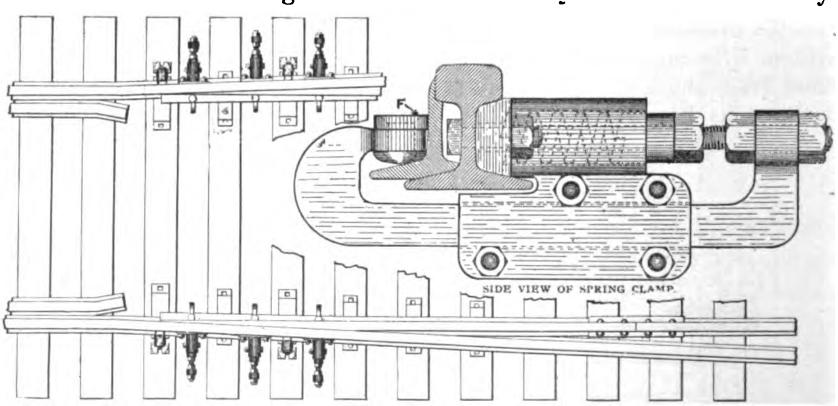


Fig. 211.—Weir Expansion Joint.

in a large city or important railway center, commonly known as "switching," is frequently carried on by a "terminal," "belt line" or "union" railway company, which may also have yard facilities of its own. The yard may be at a junction point with other roads or with branches or lines of the same road or system, where the trains are broken up and the converging traffic separated and again made up into trains for the various routes. The yard may be at a division point, where a readjustment of the make-up of some or all of the trains becomes necessary for the forward movement. The conditions requiring such a rearrangement are various. The traffic originating on the division and brought in by the local trains must be classified and distributed among other local and through trains. Some of the traffic arriving on through trains for points on the next division ahead must be shifted to local trains; and a considerable change in the maximum grades, as at the foot of a mountain division, may require a reformation of the trains on the basis of a different tonnage rating. In a yard at any point the distribution, storage or dispatch of the empty cars necessarily constitutes part of the work.

The character of the work to be done in any yard in question is thus seen to depend very largely, if not quite entirely, upon the situation respecting the traffic. The men best acquainted with yard operation are yardmasters, conductors, locomotive engineers, brakemen and switchmen; and before laying out or enlarging any yard the engineer in charge should call to his aid these different employees and with them look over the ground. As future requirements are always an important consideration, the traffic department should also be consulted. The proper laying out of yard tracks is thus seen to be a broad study, requiring time, careful investigation and to some extent the gift of prophecy.

As a first principle it may be laid down that, with roads handling any considerable amount of traffic, the yards should be so ample in capacity and so arranged that the main track need not be used in switching. In order to accomplish this, or at any rate to avoid frequent crossing of the main track, the yard should all lie on one side of it. If the road be double track the best arrangement is to have the main tracks diverge far enough to make room for the yard between them, else there must be more or less crossing at least one of the main tracks. Generally speaking, a yard should consist of at least two distinct sets of tracks or divisions: "receiving" tracks and "classification" or "distribution" tracks. The purpose of the receiving tracks is to hold trains temporarily as they arrive at the yard, permitting the main track to be cleared immediately and the release of the power and the road crew. The distribution tracks are next in order to the receiving tracks and the ones on which the cars are separated or distributed as the trains are broken up. On these tracks the cars for various routes and destinations are collected, and the different classes of freight are got together and made up into trains, and from them the trains are usually dispatched ahead. In the largest practice this division of a yard is known as the "classification" tracks, but the term "distribution" is in considerable use and more frequently expresses the purpose.

Where the traffic is so heavy that the distribution of cars must be carried on uninterruptedly a third division, known as the "advance" or "departure" tracks is made, to receive the trains as soon as they are made up on the distribution tracks and hold them while they await orders to proceed. In terminal yards such tracks would be used only by the outbound trains. The necessity for departure tracks can be dispensed with by increasing the number of distribution tracks, and at the same time shorten the total length of yard. Where, for any reasons, there may be periods in which trains in considerable numbers must be held for some time, a fourth division, known as storage tracks, is sometimes made. The necessity for still another division is sometimes recognized, but seldom provided for in this country, namely that of sorting tracks, for arranging the cars of a train in station order after being made up on the distribution tracks. Where the yard is at a division point and traffic is heavy both ways, it is convenient and customary to have receiving and distribution tracks for each direction. At terminal points the distribution tracks connect with tracks leading to the different freight stations, team tracks, elevators, docks, warehouses, etc.

Yard Design.—The tracks in the various divisions of a yard—receiving tracks, distribution tracks, etc.—are usually arranged parallel, leading off at intervals from a straight piece of track called a "ladder" or "backbone," shown in Fig. 212. All the frogs in a ladder should be of the same angle, including the frog connecting with main track or the main siding at *A*; that is, if all the tracks are to be parallel and run straight from the frogs. The frog at *A* may, however, be of different angle from that of the others, and frequently is, in which case either the ladder must leave the frog *A* by a curve or else the parallel tracks must leave the frogs on the ladder by curves, or both; also, to shorten the ladder without using frogs of undesirably large angle, curves may be introduced behind all the frogs, whether *A* be like the others or not, and such is frequently done. The arrangement of running the parallel tracks straight from the ladder is the simplest and affords the advantage of an unobstructed view from end to end of a train of cars, both sides, after it has been pushed in past the frog, thus enabling the engineer to take signals directly from brakemen coupling or uncoupling cars. In some cases where the ladder curves from the frog to make a large angle with the main track or main siding it is not possible to join consecutive parallel tracks with the same (the ladder), owing to lack of room for the turnouts. In such a case the parallel yard tracks are usually connected in sets of two or three, and only one track of the set is joined directly with the ladder. Another arrangement is to have the parallel tracks lead out from the ladder in pairs from three-throw switches, like the turnouts *X* and *Z* in Fig. 159, it not being necessary to have the frogs *F* and *F′* opposite each other, which might make the curvature of the turnout *Z* undesirably sharp. The use of three-throw split switches in this manner has been applied in the "sorting sidings" of the Midland Ry. at Wellingboro, England.

The distance between any two frogs leading from the ladder is the distance between the centers of the parallel tracks leading from them, divided by the sine of the frog angle. In the figure,

$$A\,B = \frac{B\,D}{\sin B\,A\,D}, \text{ and } B\,C = \frac{C\,G}{\sin C\,B\,G}$$

C G is, of course, equal to *E F*, the distance between track centers. This distance is sometimes assumed to be equal to the distance between track centers multiplied by the frog number. The results found by that formula are approximate. All the parallel tracks need not necessarily be the same distance apart. Table XVI (See index) gives distances between frog points or headblocks on ladders, corresponding to the number of the frog used, and for various distances between track centers.

A leader is a diagonal track crossing several parallel tracks at such an angle as to admit of connecting with each track crossed by means of a slip switch. By such an arrangement a set of receiving tracks long enough to hold two or more trains may have switch connections each train length to permit the prompt release of road engines; or the leader may be used across any set of long tracks to enable the rear portion of the cars on any track to be taken out without switching the whole string of cars, which might be longer than one engine can handle, especially under unfavorable conditions such, for instance, as through deep snow.

The switch stands on ladder tracks should be arranged on the side opposite the frogs, especially if they are to be tended by a switchman on foot, as he then has clear running space between them. Where cars are to be switched by poling, the stands between the tracks should be low enough to permit the pole to clear the stand with a lamp on. The number of the track may be painted on the target of the stand. In order to reduce the distance between the switches to a minimum, a minimum allowable distance between tracks and a maximum allowable frog angle are used. Twelve feet is about the minimum distance between track centers that is extensively employed, although yard tracks are sometimes laid as close as $11\frac{3}{4}$ or $11\frac{1}{2}$ ft., c. to c., where room is scarce. The maximum frog angle advisable is perhaps that of a No. 7 frog, giving a turnout curve of 12° 26′ for a stub switch and a curve of about 13° for a point switch. A No. 6 frog, giving a lead of about 17°, is frequently used. Where there are so many movements as there are in yards, however, much wear and tear to both rolling stock and track results from sharp turnout curves, and many think that a No. 8 frog, giving a lead curve of about 10°, should be the maximum angle to use. Where the switches on the ladder are operated from a tower, and available ground is plentiful, it is advisable to place the tracks farther apart and

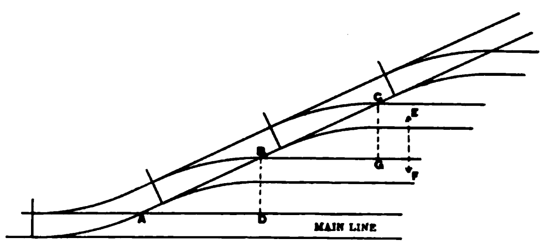


Fig. 212.—Ladder Track.

use turnout curves of still smaller degree. A spacing of 13 ft. c. to c. of tracks is quite commonly employed, even where the switches are operated by hand. Such is the spacing distance in vogue on the Michigan Central R. R. in connection with No. 9 frogs on the ladder and a No. 11 frog where the ladder connects with the main track. On the Lehigh Valley R. R. No. 10 frogs are standard for yard tracks in all new work where the available room will permit, and nothing less than No. 8 is used. Between main track and the first yard track room is usually needed for signals, water cranes, etc., and 15 ft. c. to c. is the minimum distance to be recommended. On the Michigan Central R. R. this distance is made 16 ft. So far as track work and the work of switching are concerned plenty of room between yard tracks is desirable and a convenience in many ways, and 13 ft. between centers is none too much. A liberal allowance of space between the tracks affords room for piling track material while repairs are under way and for piling snow when the tracks become obstructed in winter; it is also a measure of safety to brakemen in switching cars. It is sometimes recommended that where economy of space is important an extra width of spacing may be made at intervals of five or six tracks in order to allow for the piling of material, drainage, etc. Tracks running parallel with ladder tracks should be at least 15 ft. distant, c. to c., to allow room for trainmen to give signals, throw switches, etc., between moving trains. Although on tracks cut up as ladder tracks are there ought to be but little trouble from expansion or contraction with stub switches, still point switches are undoubtedly the better to use, since with these there is less tamping of headblocks and fewer cases of derailment.

The ruling principle in yard design is that the movements of the cars shall be forward: backward movements, at least so far as the general work of switching is concerned, interfere with orderly operation. In order to fulfill this requirement it is necessary that the switching tracks shall be open at both ends, so that traffic may enter at one end and pass out at the other, and there should be direct passage from each track in any set into any track of the set next in order. The arrangement essential to these conditions is a ladder at both ends of each set of tracks. The receiving division should be large enough to hold temporarily several trains, should they arrive at about the same time, until each may in turn be run out for the distribution of its cars according to their various destinations or the classification of the commodities. The number of tracks required in the receiving set will then depend a good deal upon the train schedule; that is, how the trains arrive—whether a large portion of them arrive within a period of a few hours or whether the service is more or less evenly distributed over the whole 24 hours.

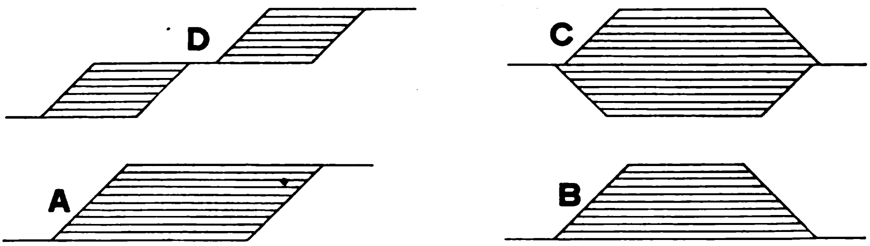


Fig. 213.—Ladder Arrangements for Sets of Tracks.

It is usually stated that each receiving track should be long enough to hold the longest train that is ordinarily hauled over the division, taking account of double headers. It is contended, however, by some careful students of practical yard design that such a length for all of the receiving tracks is seldom necessary, as trains of empty, loaded, and partly empty and partly loaded cars vary much in length, and engines of different classes are rated differently, so that it is rarely the case that a considerable number of trains entering the receiving division consecutively are of the maximum length. A committee of the American Railway Engineering and Maintenance of Way Association has recommended that when the trains of maximum length represent less than 20 per cent of the total number of trains entering the yard the average train length will then be the most practicable basis for the length of the receiving tracks, providing these tracks are all of equal length. If some of the trains are longer than the longest receiving track it then becomes necessary to cut the train and dispose of it on two tracks, and, of course, this arrangement is undesirable if it applies to a considerable portion of the traffic handled daily. Equality in the length of the tracks of a set requires that the ladders at the two ends shall be parallel (*A*, Fig. 213), but such a feature is not an essential of yard design. A set of tracks of trapezoidal outline,—that is, with ladders converging (*B*, Fig. 213)—is a flexible arrangement, and if the lengths of the tracks included cover the variation from the train of average length to that of maximum length the convenience of the scheme is apparent. In deciding upon the length of yard tracks the prospective changes in length of trains through increase in weight of locomotives and in the possibilities of grade revisions, should, of course, be considered.

The purpose of distribution tracks is to separate the cars by routes, by destinations or by commodities. Thus, in a junction yard some or all of the trains are broken up for the distribution of the cars to the lines meeting at the junction. In a terminal yard the inbound traffic must be distributed to various destinations in the locality. In a division yard the traffic destined for points on the adjoining division must be separated from the through freight, and shipments of miscellaneous products received in large quantity by local trains are usually separated and rearranged for the forward movement more or less into trains of the same class of commodities, such as coal trains; trains carrying agricultural products; general merchandise and manufactured articles; and fast freights, carrying stock, refrigerated meats and dairy products, fruits and other perishable goods. The time element in the movement of freight is a condition relevant to the distribution of cars in yards.

The number of distribution tracks required in any case is governed by the number of divisions to be made of the traffic in the regular work of the yard. The length of these tracks should be determined by the general arrangement of the yard in respect to the making up and starting of the outbound trains. In the great majority of the yards in this country the trains are made up on and start from the distribution tracks, in which case the tracks should accommodate the longest trains that are ordinarily handled; and some allowance should also be made as to the number of the tracks, so that the switching movements may proceed after some of the tracks have been filled up and the trains are awaiting orders. In this case, as in that of the receiving tracks, the trains vary in length, and it is therefore not usually necessary that all of the tracks of the set should be of equal length. By converging the ladders at the ends of the set the lengths of the tracks may be graduated from the longest required to the average length of the trains, or shorter, if desired. Where the yard includes a set of departure tracks the lengths of the distribution tracks are not so important, as in that case any congestion of cars on the distribution tracks may be relieved by running them ahead to the proper place on the departure tracks. For the inbound traffic in terminal yards the distribution tracks may usually be shorter than in division or junction yards, as the cars after being distributed are not usually handled in trains of full length. There is also another condition which has arisen during late years rendering distribution tracks of full train length unnecessary, and that is the separation of air-braked cars from those not so equipped. In making up trains the cars with air brakes are coupled together, next the engine, with the non-air cars on behind, and in order to assemble the cars in this way it is necessary to first make up these parts of the train on two tracks. Where the tracks in a yard set are more numerous than the space on one side of the ladder will provide room for, or require a ladder of undesirable length, a double or V-shaped ladder is sometimes used. By arranging the ladders at both ends of the set in the same manner, but oppositely disposed, as in Sketch *C*, Fig. 213, the longest tracks, which may be used for the heaviest business, come central, or in position most convenient to the switching movements. Tandem switches or switches entirely separated, at the point where the ladders branch from the main lead, are perhaps preferable to a three-throw switch, although the three-throw switch is sometimes used in such a place. The departure tracks should be long enough to hold the longest trains operating on the division.

Sorting tracks, for arranging the cars of a train in station order, usually consist of a series of stub tracks of short length, located conveniently to the distribution tracks, but preferably between the distribution and the departure tracks, although not necessarily in the direct line of travel. In Europe "gridiron" tracks are used to some extent for this purpose. The arrangement consists of a set of short tracks with a ladder at each end, the length of the tracks and the number of the same being arranged with reference to the capacity for holding the cars of an entire train. By shifting the cars of a train into such a set of tracks they may be pulled out at the other end in sections and in station or "industry" order. To solve the most complicated problem of sorting, the cars must be run through the grid twice or there may be a double grid, as in Sketch *D*, Fig. 213. The number of tracks should at least equal the square root of the number of cars to be switched, the car capacity of each track in that case being equal to the number of tracks. Thus, to arrange in consecutive order a train of cars numbered from 1 to 60, but promiscuously coupled, would require a grid of at least eight tracks with a capacity of eight cars each. At the first sorting the cars numbered 1 to 8 would be shifted to track No. 1, cars 9 to 16 to track No. 2, and so on; but the cars on each track would not likely be in consecutive order. At the second sorting, or on the second grid, the cars would be placed in regular order back and forth across the eight tracks. The handling of cars in this manner with an engine would require too many movements for practical switching, so that the only feasible scheme for such a system of sorting would be that of gravity operation. The most notable example of "gridiron" sorting tracks, and the one usually referred to in literature on the subject, is that of the Edge Hill yard, near Liverpool, England, where the switching is by gravity.

As a matter of practice it is not essential to any considerable saving in time or to greater convenience to have cars precisely in station or district order. The object in the regular arrangement is to avoid the handling of long strings of cars in setting out cars at sidings along the road and to reduce the number of switching movements on the road to a minimum. If the cars for each "set-out" are together and arranged with some approximation to regular order—that is, if the cars for the first few stations are next the engine, those for points at the middle of the division somewhere about the middle of the train, and so on—it is not usually worth while to rearrange them in the exact order of the stations; as under ordinary circumstances the few cars coupled in between the engine and those to be set out at some of the places will not be bothersome to handle. It is usually more important to look carefully to the order in which the cars must be placed on the side-tracks at the stations. For illustration, the coal bins at a certain side-track may be in advance of a lumber yard. In setting out cars loaded with coal and lumber, at the same time, they should obviously be arranged in proper order for unloading simultaneously; and to save the road crew the time and trouble of shifting the cars to get them in this order the necessary switching should be known to the yardmaster and be done in the yard, while the train is being made up. Cars containing explosives or inflammable substances are usually coupled in at the middle of the train, regardless of destination.

Yard Movements.—The sequence of movements in handling freight cars in yards is about as follows: After the train arrives upon one of the receiving tracks the engine is cut off and goes to the roundhouse and the train is inspected and taken in charge of a switching crew. The caboose is cut off and switched onto a track specially set apart for cabooses, and if the train is to be broken up it is run ahead to the ladder or track entering the distribution set. Here the cars are switched in accordance with classifications heretofore explained, and as the cars accumulate, upon the arrival of following trains, they are made up into newly arranged trains on the distribution tracks. Meantime the bad-order cars have been switched to the repair tracks and the "hold-for-order" cars (usually cars for which the way-bills have not been received) to the storage tracks. The cars may then be rearranged in order and sent to the departure or "starting" tracks, if the yard is so divided; if not, they remain upon the distribution tracks. The road or transfer engine is next attached, the caboose is taken on and the train is sent forward.

Methods of Switching.—In yard switching there are four methods of handling cars: namely, rear-end or tail switching, poling, shifting over a summit or "hump," and gravity switching. The relative extent to which these methods are employed in this country is about in the order named, with tail switching used in the great majority of cases. By this method the locomotive is coupled on at the rear end of the train or string of cars to be switched, and in the course of successive movements forward and back the cars are pushed or "kicked" to place on the distribution and other tracks. The track which forms the extension of a ladder or is connected with the same, and on which the movement of cars takes place in switching, is called a "drilling" track. As in this method of switching, the whole string of unswitched cars must be handled at each movement, it is necessarily slower than some other methods.

By the poling or "staking" method the train is usually run out of the receiving tracks and left standing on a track which joins with the ladder of the distribution tracks. The switch engine working on an adjoining parallel track, pushes, by means of a pole, the cars from the head end of the train, one at a time, or as many at a time as are found together belonging to the same destination or lot, commonly called a "cut." Sometimes a double cut is started in one movement. When such is done the pole is placed against a car in the first cut and the man who works the couplers rides between the last car of the first cut and the foremost car of the rear cut. As soon as the whole string of cars is got up to good speed the coupling between the two cuts is slipped and steam is crowded on to put the first cut the desired interval ahead for the two switching movements. But if the cars are to be weighed, they are passed over the weighing scales one at a time, and on down the ladder of the distribution set until switched to the proper track. As by this method the whole train or string of unswitched cars does not have to be moved each time a car is shifted, it is widely in favor, and is employed in a large number of yards.

Where the ground is level the engine must follow the car some distance and give it a flying start. As hard-running cars are liable to stop on the ladder, it is well, where it can be done, to extend the poling track alongside the ladder. In both tail switching and poling it is an advantage to have an assisting grade entering the distribution tracks, as then the cars do not have to be shoved so hard to send them to place. A descending grade as steep as 0.4 or 0.5 per cent is desirable, as then the cars have only to be given a start from the train, after which they will continue running.

To keep an engine busy at poling cars it is necessary to have quite a large crew of brakemen (seven to sixteen or more, according to the length of the yard) at the ladder to catch the cars and ride them to the proper stopping points. The method cannot be employed economically, therefore, unless there is a large amount of traffic, involving a good many classifications, to handle. In some long yards where there are large crews of car riders working with the poling engine there is a third track running parallel with the poling track, ladder and distribution tracks, on which a pick-up engine and flat car are kept running to and fro to bring the men back to the poling engine after they have ridden their cars to the proper places.' In this way fewer brakemen are required to keep the poling engine busily at work than would otherwise be the case. Among places where this practice of operating a pick-up engine is to be found may be mentioned the Altoona yard of the Pennsylvania R. R. and the Galewood yard (in Chicago) of the Chicago, Milwaukee & St. Paul Ry. There is a good deal of complaint against the work of poling during dark nights, principally on account of the damage caused by hard-running cars which stop short of the intended point and are run into by the next car switched. As the cars must be given a good start before they leave the ladder, and as the same brakeman is not likely to ride a car down the same track twice in succession, a car which stops short, being in the way of the car following, is liable to do a good deal of damage. In defense of poling it may be said, however, that the presence of a poling track is no hindrance to tail switching, which can be resorted to on dark nights.

The switching pole is sometimes attached to the pilot beam of the engine and sometimes it is attached to a special poling car coupled with the engine. The standard poling car of the Pennsylvania R. R. is 20 ft. long, with a strongly braced frame to stand the racking stresses. The pole is 6 ins. in diam., 10 ft. 1 in. long and is pivoted to a heavy casting bolted against the side sill at the middle of the car. The pole can swing outward to any angle with the side of the car and is raised or lowered or steered into the poling socket on the corner of the freight car by a lever balanced over a post and attached to a stay rod running out to a connection near the end of the pole. There is a longitudinal foot board the full length of the car, each side, and across one end, and a railing 3 ft. high around the ends and sides of the car. The car is mounted on two 4-wheel trucks, is ballasted with old car wheels to hold it down to the track, and in the middle of the car there is a cabin 5 ft. 9 ins. long and 3 ft. 9 ins. wide, furnished with a stove. On some roads the pole consists of an iron or steel strut with a claw or angular-shaped casting on the end to fit against the corners of the cars.

In the "hump" method of switching, the track between the receiving and distribution divisions passes over a mound, so as to rise to a summit. The train is pushed up to the summit by a switch engine and the cars, being cut loose one or more at a time, run down the other side by gravity and are switched onto the different distribution tracks. Usually there is a level track running around the hump to connect the two divisions of the yard, so that trains not to be switched need not be sent over the hump. The hump arrangement is in service in yards on the Philadelphia & Erie; Pittsburg, Cincinnati, Chicago & St. Louis; Vandalia; Chicago, Lake Shore & Eastern and other roads, and is becoming quite popular. In the yard of the road last named the cars pass from the hump over weighing scales and are switched upon the distribution tracks at the rate of one car every half minute from the time the first car is put over the summit. Hump switching is supposed to have been first applied at Speldorf, in Germany, in 1876, and is now extensively used in both France and Germany, where it is commonly known as the "ass-back" (dos d'ane) method of switching. The grade is usually steepest on the leaving side of the hump, running from 0.9 to 3.0 per cent in various yards, according to the length of the incline. In one of the yards of the Paris, Lyons & Mediterranean Ry. the grade of the hump is 1 per cent, and to balance the resistance due to the switches, curves, frogs and guard rails the turnouts are on a grade of about ½ per cent leaving the ladder, the remaining portion of the distribution tracks being level. Before the cars are put over the hump there is marked on the front end of each car or cut of cars the number of the switch it is to enter, and on the back end of the last car in each lot is marked the number of the switch to be opened for the next car following, thus giving the switchmen notice in advance. A man at the summit uncouples the cars at the points indicated by the chalk marks. When cars are being shifted at night the switch numbers are called out by the yardmaster. In this country it is usual in switching movements for the brakeman riding the cut to indicate to the switch tender by hand or lamp signals the number of the track onto which the cut is to be switched.

A gravity yard is one wherein the switching throughout is by gravity alone, the grades of the different yard divisions or sets of tracks being such that the cars will start upon releasing the brakes. For such operation grades of 0.8 to 1 per cent are required, the steeper grades being necessary where the winters are cold, as the freezing of the journal packing makes the cars run hard. In this country there are but few if any yards worked entirely by gravity, but in numerous instances grades are used to assist in the yard movements. In some instances all of the movements are started by locomotives, the grade then being sufficient to enable the cars to hold their speed through the switches and on the standing tracks. Grades of 0.5 per cent on drilling, poling and ladder tracks and through the turnouts, and 0.25 to 0.3 per cent on standing tracks are about right for such work. In other instances the grade of the lead or drilling track is made steep enough to give the cars such a start upon releasing the brakes that they will continue running upon the lighter grades of the standing tracks, but in this country it is seldom that the grade of standing tracks is made steep enough to start cars by gravity alone. Thus, in one of the terminal yards of the Pittsburg & Lake Erie R. R. there is a lead on a grade of 2 per cent for a distance of 200 ft. ending at the point of the first switch, followed by a grade of 0.4 per cent through the switches and that by a grade of 0.3 per cent on the standing tracks. As examples of the arrangement first named, the Galewood yard of the Chicago, Milwaukee & St. Paul Ry. is on a grade of 37 ft. to the mile (0.7 per cent) throughout, and the Altoona yard of the Pennsylvania R. R. is laid to a uniform descending grade of 32 ft. per mile (about 0.6 per cent) in the direction of the switching movements. In both of these yards the switching movements are started by a poling engine. The Galewood yard, which is exceedingly compact and well designed for economy of space, is described and illustrated in the Railway Review of Oct. 22, 1892.

In Europe, where gravity switching is more generally employed than in this country, the cars are lighter, as a rule, and the brakes are arranged at the side, so that the brakemen assigned to catch the cars as they enter the distributing tracks do not have to get upon the cars to stop them. In addition to the car brakes, "shoes" or "skates" are quite commonly used to assist in stopping the cars. These devices are inclined castings or wheel chocks grooved to fit over the rail and slide under the weight of the wheel when the same runs upon it. When the car stops, the wheel rolls back off the incline and releases the shoe. To have them convenient for use they are distributed along on the ballast, between the tracks, at intervals of 50 to 60 ft. For catching runaway cars, on which the brakes have failed or which get beyond control through other cause, "chain drags" are in considerable use. This device consists of a chain of large size weighing four or five tons, stretched out in the track or coiled up in a well under the track. At the end of the chain is a large hook which can be raised by a lever in control of a switchman. If a car gets away the hook is thrown

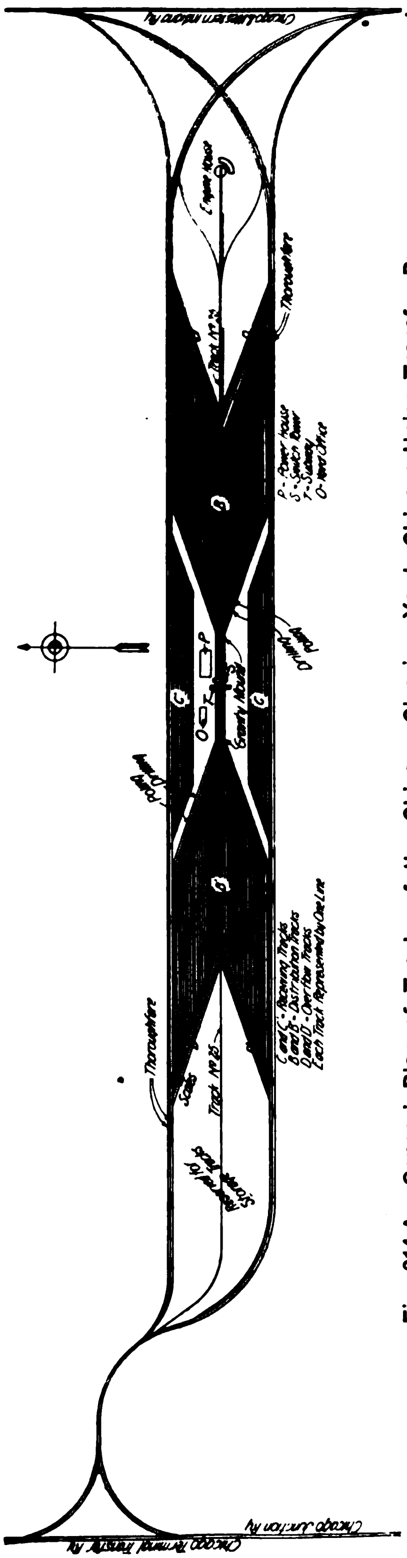


Fig. 214 A.—General Plan of Tracks of the Chicago Clearing Yard, Chicago Union Transfer Ry.

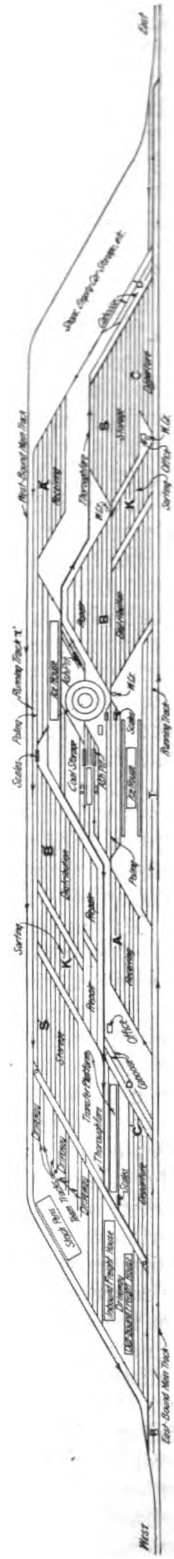


Fig. 214.—Typical Division Freight Yard Layout.

up to catch an axle of the car, and the heavy chain dragging over the ties soon brings the car to a standstill. Sand tracks (Fig. 180) are also in use for the same purpose.

Yard Arrangements.—In treating the subject of yard tracks it is conventional to illustrate the application of the principles of yard design by typical plans. As the requirements of each yard depend largely upon the traffic situation and conditions peculiar to the locality, it is seldom if ever that such plans are closely followed in practice, but they serve as a basis for the consideration of yard movements, and in this way may be of some value. Where an abundance of space is available there is no difficulty in arranging yard tracks to suit almost any of the requirements for switching cars, and the study of yard design is much simplified. In working out typical plans economy of space is therefore one of the prime considerations. A fascinating scheme is to design a layout of east-bound and west-bound yards lying opposite each other between separated double tracks, with a roundhouse between the yards. While such a location for a roundhouse is not the one usually chosen in practice it is nevertheless recommended by practical students of yard design, and a consideration of the advantages in such a layout is interesting. In putting such a layout on paper it is customary to have the outlines of the same symmetrical with respect to an axis formed by extending the main tracks straight through the yards. Such a condition is not, however, an essential of space economy or to any special convenience, and land is no more likely to be available in that shape than it is if selected to lie entirely upon one side of the general alignment of the main track, in which case only one of the main tracks need be deviated from the general course.

Figure 214 shows a layout of division freight yards for traffic in two directions, each yard containing four main divisions, namely, receiving, distribution, departure and storage tracks. The two yards, east-bound and west-bound, are duplicates as to facilities, but for sake of showing a variety of arrangements they are not laid out in exactly the same manner. The receiving tracks for east-bound movements are located at *A*, the distribution tracks at *B*, leading from a double or V-shaped ladder, with sorting tracks for the local trains at *K*. The tracks *S* may be used for storing cars detained for shipping orders and in emergency for the overflow of the distribution tracks. The departure tracks are indicated by *C*. For the west-bound movement the corresponding divisions are indicated by *A'*, *B'*, *K'*, *S'* and *C'*. The figure is not drawn to scale and the frog angles have been purposely exaggerated. No significance attaches to the number of the tracks in each division of the yard, as such could in any case be arranged to suit requirements. In constructing a yard for a growing business, room for additional tracks should be left between *A* and *B'* and between *A'* and *S*, or by spreading the main tracks farther apart room could be had for extensions to all the ladders.

In locating and laying out a yard the future extension of the system without materially changing or abandoning the original tracks should be in view, and the matters of grades and drainage are, of course, important. To locate a double yard such as is here shown, on a descending grade throughout its whole length, would favor the yard for traffic in one direction and operate against that for the other direction. In a situation of this kind the arrangement would usually be changed: the receiving tracks for both yards—that is, for traffic in both directions—would be located at the upper end, and the switching in both yards would all be done in the direction of the falling grade. In the Altoona yards of the Pennsylvania R. R., where the grade descends toward the east (32 ft. per mile) the whole distance, the switching movements in the west-bound yard proceed from west to east the same as in the east-bound yard. In the west-bound yard the receiving tracks lie west of the distribution tracks, so that trains arriving from the east must pull on by the distribution tracks in order to enter the receiving tracks. The best location for a double yard is one which divides the two yards across a summit, but it is seldom that ground with conditions so favorable can be found where yards are needed. In order to obtain the assistance of grades it is sometimes necessary to run the yard tracks out at an angle with the direction of the main line instead of parallel with it.

The poling track connecting divisions *A* and *B* is arranged between two standing tracks, the idea being that while the poling engine is at work with cars on one of these tracks a switch engine in the rear may run a train to position on the other track, thus keeping the poling engine steadily engaged at the work of poling. In order to give room for the poling engine to begin work on the train the poling track should be a quarter to a third longer than the longest trains to be put through the yard. For the east-bound movement there are weighing scales on each standing track, near the advance end, the advantage of the arrangement being that there is a set of scales in reserve in case either set gets out of order. Between divisions *A'* and *B'* the scales are located in the throat, just in advance of the distribution tracks, where they catch every car passing through the yard, and hence it is immaterial which track is used for poling. A piece of "dead" track is usually gantleted with the track passing over the scales, so that cars which do not have to be weighed may be switched over the same and pass without bearing upon the scales. It will be noticed that the ladders branch from a principal side-track *T*, which serves as a "running" or "thoroughfare" track along one side of the yards. At the west end it connects with the main track by a crossover and extends past the same, forming a "run-by" *R*. This arrangement obviates any necessity for fouling main track in switching movements, as the run-by permits trains to back past the crossover without using it. The run-by is here shown merely for the purpose of illustration, and not because it is needed in this particular yard.

A question of importance is the location of caboose tracks Cabooses should be left where they will not be disturbed by the shifting, as oftentimes they are used by the crews for sleeping quarters. A good arrangement is to have two tracks: one for the cabooses of regular trains and another for those of the extras. Those for regular trains can then be taken out in consecutive order, so that no shifting is required; while those for irregular trains will usually be taken out in the same way, the common rule being "first in, first out." A location for these tracks has been selected at *D*, being near the point where the caboose enters the yard and near to the set of tracks from which the train will depart that will take the caboose on its return trip. In any case caboose tracks should be double ended, and when located as at *D'*, it is an advantage to have the tracks elevated sufficiently to form a short incline at the outlet end. With such an arrangement the service of a switching engine to deliver the cabooses to outgoing trains is not needed, as each train when leaving the departure tracks *C* may stop with the rear car just past the switch leading out of the caboose track, and the caboose may be pushed out by hand and coupled on.

It is desirable that the engine house or roundhouse should be so located that ingress and egress between it and main track cannot be blocked by the movement of trains in the yard. Where it is between two yards, as in Fig.

214, it is necessary to cross drilling tracks, and some interference in this respect cannot therefore be avoided. As, however, the liability to obstruction in every case is by moving trains, serious delays are not to be expected. In connection with the roundhouse there must be facilities for supplying coal, water and sand, ash pits for cleaning the fire boxes and means for turning the engines. It saves time to take water and sand while the engine is coaling, and usually the water cranes and sand bins can be located to permit this to be done. The usual arrangement in connection with an ash pit is a depressed track alongside for spotting cars to haul away the cinders. (This subject is treated fully in § 178, Chap. XI). Coaling, watering and ash-cleaning facilities are usually located on the track leading into the engine house, but sometimes on both the outgoing and incoming tracks on opposite sides of the engine house; and sometimes the outgoing and incoming tracks are on the same side of the engine house and separated to permit the location of coaling pockets between them. To prevent the obstruction of the passage to the ash pit or engine house by engines that are taking on coal, water etc., there should be a run-around track, as shown in Fig. 214. In large yards it is well to have water cranes at convenient points some distance from the roundhouse, as they save time which would otherwise be consumed by the switching engines in running back and forth to take water. In yards where trains pass through unbroken, without detaching the locomotive, facilities should be provided for taking coal and water and dumping cinders on the thoroughfare track. A line of water pipe, with hydrants or hose attachments at intervals for the use of inspectors and repair men, is a great convenience.

The repair tracks for bad-order cars should be convenient to the drilling or poling track, so that the separation of these cars from the rest may take place while the train is being broken up and shifted into the distribution tracks, and without extra movements. It is desirable that repair tracks should be short—not to exceed 15 or 20 car lengths—and in order to secure the necessary room to work upon the cars they should be spaced farther apart than the usual distance between yard tracks—say 18 or 20 ft. c. to c. A convenient arrangement is to lay these tracks in pairs about 16 ft. c. to c., with a clear space of 25 or 30 ft. between the pairs for piling material in case cars have to be unloaded. If the room is scarce part of the tracks may be spaced 16 ft. centers and used for light repairs, while for cars needing heavy repairs other tracks may be spaced farther apart. It saves a good deal of switching and delay to put the cars needing only light repairs on tracks separate from those occupied by cars requiring heavy repairs. In estimating the capacity of repair tracks allowance should be made for an open space of 10 or 12 ft. at each end of each car, for handling material and for convenience of the repair men in other ways. This arrangement requires 45 or 50 ft. of track for each car. The space set apart for material supplies should be at one end of the repair tracks, so that it can be easily trucked into and along the openings between the tracks. In Fig. 214 the repair tracks in both east-bound and west-bound yards lead from the distribution ladder.

The ladder for the storage tracks S leads from a continuation of the poling or drilling track through the distribution division B, and therefore admits of straight-ahead switching into the storage division. The order of operation would usually be to take the string of cars accumulated on the said "continuation" track in the course of breaking up one or more trains, and then tail-switch them into the storage division. The ladder for the storage tracks S' also leads from a continuation of the poling track past the distribution division B'. No storage track should be so long that a switching engine cannot handle all the cars it is capable of holding.

The location of ice houses and tracks for icing refrigerator cars is important, and in order that the work of icing may proceed without delay the arrangement should be such that the cars will be switched directly to the icing tracks while the train is being broken up. In Fig. 214 the icing tracks are located between the receiving and distribution divisions, lying next the tracks on which the cars stand for poling. With this arrangement the cars to be iced would be set out by tail switching before the poling of the cars in the remainder of the train would begin. The icing of solid trains of refrigerator cars not to be rearranged in the yard could take place on the track south of the ice house without sending the train through the receiving division. Another arrangement would be to have the ice house stand alongside one of the outer tracks of the distribution division, but as yards should be laid out with a view to enlargement, if necessary, ice houses and other permanent structures should not be located where they will obstruct the extension of the system.

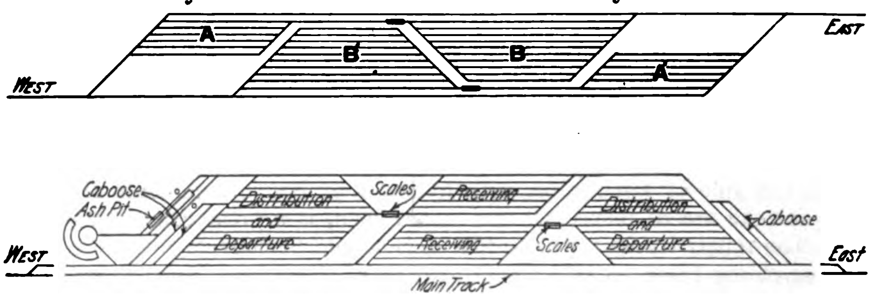


Fig. 215.—Division Freight Yard Layouts.

The lower engraving of Fig. 215 shows an arrangement for economizing space by locating the receiving tracks of a double yard side by side. The connections as drawn are for a single track, but the layout is equally feasible between the separated lines of a double track. The outer track of the receiving set may be used as the drilling or poling track, or, as is frequently the case in practice, poling may be done on any of the parallel tracks of the receiving division. The receiving and distribution tracks of each yard might, however, be separated far enough for a poling track between, as in Fig. 214, which would leave considerable open space to the east of the east-bound rceiving tracks and to the west of the west-bound receiving tracks that might be utilized for storage tracks or other purposes. By the arrangement shown the bad-order and "hold-for-order" cars would be held on certain tracks of the distribution set, as is commonly done in practice. In case yards arranged in this manner were designed to lie between the separated tracks of a double-track road, the outlet ladder of the west-bound "distribution and departure" division would run diagonally the other way, or from southeast to northwest. The upper engraving in Fig. 215 shows another arrangement for making most use of land at disposal, A and B being respectively the receiving and distribution divisions for the east-bound movement and A' and B' constituting the west-bound yard. With this formation as a basis a double yard of larger functions might be developed.

Yard Accessories.—In addition to the facilities already named there are numerous arrangements which have an important bearing upon yard operation and the handling of freight. For the safety of the main-line traffic, where full speed is maintained past the yard, connection should be made with main track only at each end of the yard, and each of these connections should be operated under the protection of interlocked signals. The usual practice where interlocking is not employed is to put up "Yard Limits" sign boards far enough out to protect trains using the switches at the ends of the yard, and require that between these limits all trains shall proceed with caution. For the working of a large number of yard switches some form of machine operation from a central tower is preferable to hand-throwing stands on the ground. In yards the interlocking of switches is not usually necessary.

The switches on the distribution ladder in the Altoona yard of the Pennsylvania R. R. are thrown by compressed air cylinders controlled by electro-magnets operated from push buttons in a tower. The switch movement is of the direct-acting type, the switch points being connected to the piston of the air cylinder without the locking movement. The arrangement of the valves admitting air to the cylinder is the same as on the regular Westinghouse electro-pneumatic switch movement (described in the following section and illustrated by Fig. 225), with the exception that the lock cylinder and magnet are dispensed with. The push buttons are arranged in two rows along the side of a box, two buttons for each switch, the one in the top row serving to close the switch and the one in the bottom row to open it. All of the 24 push buttons or keys can be conveniently reached by a person standing or sitting in one position. The ladder and tracks leading from the same are divided by insulated joints into blocks embracing each turnout, and one of the point rails of each switch is insulated from the main rail. On the operating board, above the set of keys for throwing each switch, is an indicator, in circuit with the insulated rails of the switch and turnout. Normally, that is when the ladder track is clear, the indicator shows white, but if a car comes upon the block on the ladder, or within fouling distance of the frog, on the turnout, or if the switch has not completed its throw the aperture of the indicator will show a red target. The operator is therefore able to follow the course of each car by the successive appearance and disappearance of the indicators, and the switching movements can take place as fast as the cars can be shunted at safe intervals. As a matter of record, 133 cars have been switched in an hour, and an average rate is 95 cars switched per hour. The operator is provided with a schedule of movements required to distribute the train, and the only observance necessary on the part of the switching crew is to send the cars along at the proper intervals. The air pressure is 60 lbs. per square inch and the furthest switch operated is 1500 ft. from the tower. The machine and circuits are more fully described in the Railway and Engineering Review of Aug. 28, 1897.

Team tracks, upon which cars are spotted to be loaded from or unloaded into wagons, may usually be arranged to best advantage as a series of short parallel spurs branching in pairs from a ladder track, as shown at the left in Fig. 214. These tracks may hold 10 or 12 cars each and should stand at as large an angle to the main lead as may be practicable —say 45 to 60 deg. The two tracks of each pair may be spaced as close as 11 or 12 ft. c. to c., but the driveways between the pairs should be 40 ft. wide, so as to afford room for teams to back wagons against the cars and still permit teams to drive between the team in this position and a team on the opposite side of the roadway. To facilitate the prompt removal of freight during all seasons of the year the driveways should be well paved or planked. A planked driveway across the team tracks, alongside the main lead, affords the team ingress to the driveways, so that all the outbound teams may drive straight ahead, without turning around. By this arrangement of tracks empty cars may be removed or loaded cars placed without disturbing any considerable number of persons engaged with teams at loading or unloading other cars.

Freight houses, for handling less than car-load merchandise freight, are usually long buildings with parallel tracks closely spaced, on one side, and a driveway for teams on the opposite side. By placing the cars on the several tracks so that the doors stand opposite one another the loading or unloading of the freight may proceed by trucking from or to the freight house through the car doors. There is, however, by this plan of working some interference between empty and loaded trucks in passing one another, and in switching considerable time is consumed in spotting the cars with their doors directly opposite, and again in coupling up when the cars are hauled away. It adds to the convenience of trucking and switching to have a platform 8 or 10 ft. wide between each pair of tracks, as then the trucking need not be done in direct lines and the cars need not be spotted to stand with the doors exactly opposite. Where a large volume of business is handled it is customary to have separate houses for inbound and outbound freight. To limit the trucking distance from the point of delivery by team, outbound houses should not be wider than 24 to 30 ft. Inbound houses may be 50 to 80 ft. in width, as, owing to the necessity of unloading freight into the house and holding it for delivery, more room is required than in outbound houses. The width required for a stated capacity depends, of course, upon the length of the building. As cars at inbound houses can be unloaded rapidly there is usually no advantage in having more than two tracks at the house, in which case it is only necessary to unload through one car. At outbound houses the situation is different, for cars must ordinarily remain at the house a considerable time, perhaps all day, to receive a full load, so that, in large cities, the cars which must be set to load for shipment to many points require a number of tracks, making it necessary to load through four or five, and sometimes through six or seven, cars.

An outbound freight house should be so located with reference to the inbound house that the cars made empty at the latter can be moved quickly and without interference to the outbound house for loading. In some cases it might be feasible to build the houses adjoining, so that cars made empty at the inbound house could be loaded from the outbound house without being switched. Another advantage in having the outbound and inbound houses close together is that wagons may deliver a load to the one and take a return load from the other without loss of time in light mileage. An arrangement that is sometimes provided where inbound, outbound and transfer houses are consolidated at one point is to have parallel stub tracks, with the inbound house on one side, the outbound house on the opposite side and the office between them, at the stub ends of the tracks. Car-loads to be transferred are spotted on the various intermediate tracks, which are separated by platforms for trucking. An advantage in a layout of this kind is that the cars unloaded at the inbound house may be quickly turned over to the outbound house, or, perhaps they may be loaded for outbound shipments without being switched. Such a layout of tracks suggests another type of freight house, which abuts upon a street with tracks running up to its rear side at right angles. Between each pair of tracks there is a covered platform about 12 ft. wide on which freight may be trucked to all the cars without passing through any of them.

Freight houses which stand parallel to a street should set back from it at least 20 ft., so that when wagons are backed up against the house the teams will not obstruct the street. The roadway leading from an inbound house and the approach to an outbound house should not be so steep as to burden the teams of the locality. In this connection it is well to take into consideration that in a city where the streets are level or nearly so, teams are generally loaded heavier than in hilly cities and towns. To obviate the necessity of spotting cars at freight house doors it is usual to have a platform 8 or 10 ft. wide on the track side of the house. On the Michigan Central and the Louisville & Nashville roads freight houses are built on what is known as the "continuous door" arrangement. The whole side of the house is taken up with a series of doors which slide past one another. A door can be opened at any point, and there are no posts in the side of the house. No matter where a car is placed, a house door can be opened opposite the door of the car. At such a house it is not necessary to have a platform between the first track and the house to avoid spotting cars.

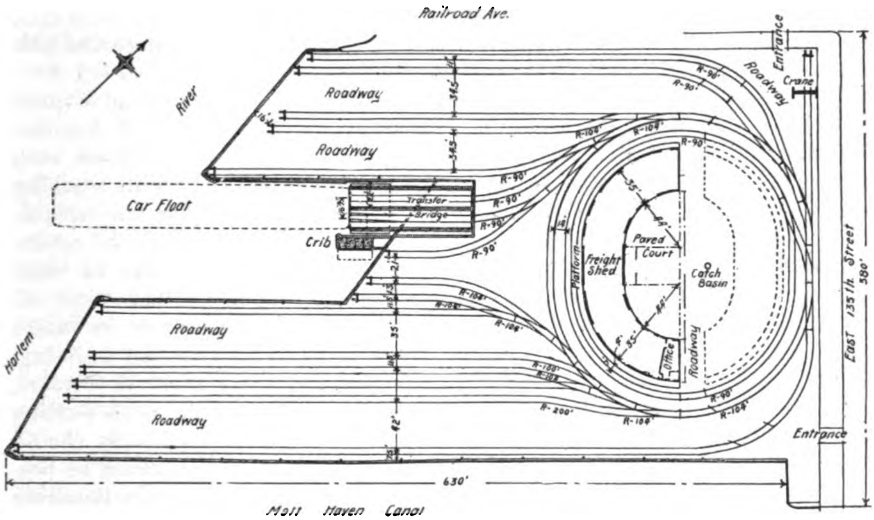


Fig. 216.—Freight Terminal of Harlem Transfer Co., New York City.

At freight houses it is desirable to have a crane for transferring heavy loads from cars to wagons or from wagons to cars. A revolving crane is an ordinary arrangement, but an overhead crane spanning two tracks, a platform and a driveway is a more flexible arrangement, as it may be used to transfer loads from car to car, to platform or to wagon. In the vicinity of busy freight houses there should be a small auxiliary yard or set of tracks holding at least as many cars as the freight house tracks accommodate. With such an arrangement the cars at the house can be pulled out and new loads or empties set in with a minimum delay to the work of loading or unloading at the house. At an inbound house, for example, a cut of loaded cars can be shoved in as soon as a cut of empties is pulled back to one of the auxiliary yard tracks. The necessity for such auxiliary tracks is obviously greater at inbound than at outbound houses.

An interesting freight terminal of the loop type, designed by Chief Engineer Walter G. Berg, of the Lehigh Valley R. R., and built for the Harlem Transfer Co., on a city block 330 ft. wide, at 135th St. and Railroad Ave., New York, is shown as Fig. 216. The terminal is planned for the business of receiving and delivering freight, either in car-loads or in less quantities. The cars are transferred on the usual car transfer boat operating in connection with transfer bridges, to or from any of the railroad trunk line terminals on New York harbor. The striking feature of the design is the complete loop, from which the side-tracks and connecting lines diverge. A short tangent inserted in the loop track permits a cross-over to be laid to an interior loop track distant 14 ft. c. to c., which serves as a standing track for an oval-shaped freight house 240 ft. long, with an interior courtyard for teams. All the driveways have block paving. The switches are of the split pattern, 10 ft. long, with ground-throw stands. The minimum curve radius is 90 ft. The gage on these curves is widened ½ in., and the outer rail is elevated 2 ins. The switching engine is a 4-wheel inclosed tank dummy locomotive, 27 ft. long over all, 6 ft. 6 in. wheel base, 44 in. wheels, 17 in. x 24 in. cylinders, and weighing about 90,000 lbs. There is no difficulty in passing cars around these curves, but special long links are provided for coupling, as with couplers of various kinds some difficulty is had with links of ordinary length. With locomotives of short wheel base and special coupling bars freight cars of ordinary construction may be handled on curves laid to a 50-ft. radius, but the wheels of long cars that are low hung will cramp against the sills on curves of 100 ft. radius and perhaps longer.

In reference to tracks at water-front terminals the following is quoted from a committee report to the Roadmasters' Association of America in 1893: "Where piers and warehouses are built with a dock on each side, from one to three tracks down the center of the pier, with trucking space on the outside, between the tracks and the edge of pier, are needed. Where warehouses are parallel with the wharf front, space can be economized by having tracks enter the building at the side and run at right angles therewith, or nearly so, and about half way across the width of the building. This method of layout will give more car room, or rather more loading room, than where the track is parallel with the building. This is especially the case where tracks are in pairs, say at 12 ft. centers, with trucking space of 15 to 20 ft. between one pair and the next, putting in as many sets of tracks as are needed. The ends of the tracks should be within a reasonable distance of the wharf front, to save as much as possible in the work of trucking, a very considerable item of cost in handling freight. Tracks abutting on wharves or ending in warehouses should be level, or there would be danger of running cars into the water, or against the building."

The transfer of freight by hand for the consolidation of less than car-load freight into car-load lots and for the release of cars at the end of a company's line is usually made across or through a long platform, shed, or freight house 16 to 20 or 25 ft. wide, between parallel tracks. For the transfer of cotton and other commodities in bales a less distance between the cars is more convenient, and platforms not wider than 10 or 12 ft. are desirable. Transfer platforms should be at the proper hight for trucking in and out of car doors, and to protect goods from wet weather they are frequently covered. There should be a bridge crane spanning two closely spaced tracks, with a trolley hoist for lifting heavy masses, like large stones, machinery etc., to be transferred from flat car to flat car. A common arrangement for the transfer of grain is high and low tracks, side by side, at a difference of elevation of 5 to 6 ft. and spaced about 10 ft. 6 ins. c. to c. The cars are spotted on these tracks with the doors opposite and the grain is shoveled into chutes running from the higher to the lower cars. For the transfer of coal, high and low tracks side by side may be used, but coal-handling machinery is the modern means, where large quantites have to be handled. The coal is dumped from or scraped out of the cars into a pocket or pit under the track, whence it is taken by a conveyor and elevated for shooting into other cars (gondola or box) standing on a parallel track. An account of a large plant of this kind operated by the Erie R. R. at Hammond, Ind., is given in the Railway and Engineering Review of Oct. 12, 1901.

The lighting of yard tracks for night work is recognized as a desirable facility. The best means for this purpose seems to be a system of electric arc lamps distributed about the yards on high poles, but the arrangement is not always entirely satisfactory, owing to the shadows cast, which bother the trainmen to some extent. By using a sufficient number of lights, however, the shadows are not so dark as otherwise, and are not so troublesome. Arc lights should not be located where they will obscure main-line signal lights. To expedite yard work it is also necessary to have telephone connection between the various offices and stations about the yard. The yardmaster is usually located near the roundhouse or middle of the yard, and in large yards there are assistant yardmasters near the ends of the yard. Telephone connection between the signal tower at the entrance to the yard, the roundhouse, weighing scales and the various yard offices is especially convenient. Some yards are supplied with air, so that trains can be charged and tested before the engine is coupled on.

A common and convenient arrangement for a passenger-car cleaning yard is a series of parallel tracks 20 ft. apart centers, or in pairs about 36 ft. centers with the tracks of each pair 16 ft. apart centers. In some cases the yard is connected at both ends, but usually it is composed of stub-end tracks with a car-cleaners' supply building at the dead end and at right angles to the tracks; if the yard is connected at both ends this building is located at one side. With the former arrangement space is reserved at the ends of the tracks for trucking material to the openings between them. These openings are paved or planked, and between alternate tracks water, steam and air pipes are laid, with connections about 50 ft. apart. Plants for supplying gas or electricity are installed in the vicinity. The yard should be drained and lighted for night work. The yard is usually located near the terminal station, and the tracks should be long enough to handle trains without cutting them. Where sufficient room is available a Y-track is usually provided for turning trains.

Definitions.—Tracks are said to be arranged in parallel when they have a common cross connection at one or both ends (Engravings *A* and *B*, Fig. 213). It is not essential that they should be absolutely parallel in direction. Tracks are said to be connected in series when the general route through them is continuously forward (Engraving *D*, Fig. 213, shows two sets of tracks in series, and sets *A* and *B* in Fig. 215 are in series).

A railroad yard, as understood in practice, is a system of tracks for switching cars in making up, distributing or rearranging trains; or for the exchange, separation, accommodation or storage of cars. The unit of a yard layout is a set of tracks arranged in parallel, and a yard may consist of one or more of such units connected in series, or otherwise disposed. When the facilities are duplicated as to traffic in two directions, or as to separate channels of traffic in the same direction, the systems composing the same are then recognized as distinct yards, and the combination is commonly known as a "double yard," or as east-bound and west-bound yards, etc. (Fig. 214).

In order to constitute a yard the layout of tracks must form a system. The test as to whether a layout constitutes a yard or only a portion of one, depends upon the completeness with which it serves the purpose of the traffic handled through it. Thus, a single set of tracks branching from a ladder, as in *B*, Fig. 213, if used for all the purposes of receiving, distributing and forwarding trains or parts of trains, would be a complete yard; but if it was used in connection with a set of receiving tracks, it would then be only part of a combination fulfilling a terminal purpose, and would not be a complete yard. Different sets of tracks, as receiving, distribution, departure, storage or other tracks, when used in one combination, are therefore not separate or distinct yards. An isolated system of tracks, as when a set is used for storage, is a yard.

The term yard is used with the same latitude of expression that is conveyed when speaking of a house. A building used as a residence, even if composed of but one room that answers the various purposes of cooking, eating and sleeping combined, is a house; and any one of the several combinations to be had by adding a bed room, dining room, parlor, bath room, etc., does not constitute anything more than a house.

A terminal includes all the facilities provided by a railway at the end of its line, or at division or junction points, for the conduct of its business, such as yards, engine houses, coaling stations, elevators, docks, warehouses, freight and passenger stations, etc.

Some Yard Layouts in Service.—To further illustrate the application of some of the aforementioned principles of yard design reference may be made to two or three existing yards. At Harahan, La., nine miles from New Orleans, the Illinois Central R. R. has an extensive layout of yard tracks with assisting grades, that is commonly known as a gravity yard. As may be seen in Fig. 217, the tracks entering the yard branch from the main line by a "Y" having double-track legs, converging into a double track running directly north and south, and nearly at right angles to the main line, the particular object in following this direction being to secure a large area which was free from public road crossings. The site selected covers a tract about one-half mile wide and three miles long, comparatively free from obstructions of the kind referred to. The portion of the yard as first constructed is shown in full lines, the dotted lines indicating extensions. The double-track branch line leading from main track passes to a receiving division containing 10 parallel tracks each 2,000 ft. long, and having a capacity of 500 cars, into which all south-bound trains are taken. Each train is then taken to the gravity lead, which is 2200 ft. long, on a ½ per cent grade, with a poling track alongside. Here the cuts of cars are started by a poling engine and pass to either of two sets of distributing tracks arranged in the shape of a fish tail along diverging ladders, each set having 17 tracks and a capacity for 832 cars. The tracks in one of these sets take even numbers and in the other set odd numbers. In switching, cars laden with coal and export freight which is to be held

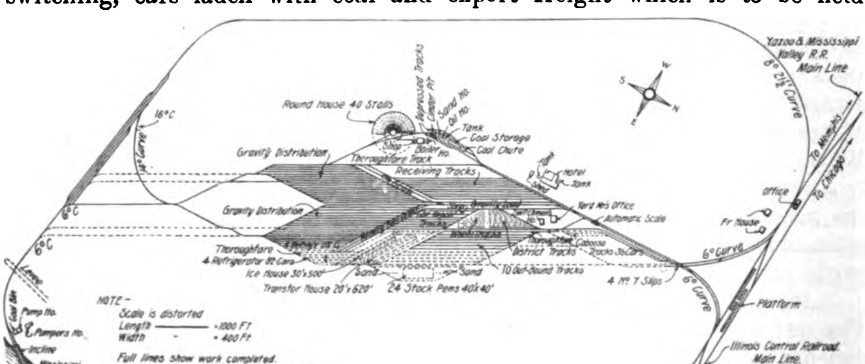


Fig. 217.—Gravity Yard, Illinois Central R. R., Near New Orleans.

for orders are sent to the odd-numbered tracks, while the even-numbered tracks take care of cars to be delivered to the various docks, cotton sheds, connections with other roads, the various yards about New Orleans, etc. Near the entrance to the ladders, on the double lead track, there are cross-overs for diverting cars from one track to the other. Cars loaded with commodities to be weighed are shunted onto the scale track, which runs between the south ladder of the receiving division and the north ladder of the west set of distribution tracks. On the rear end of each car or cut of cars sent down the gravity lead is chalked the number of the track for which the following car is destined, thus giving the switch tenders time to throw the switches, as heretofore explained. At the south end the distribution tracks have an outlet into a long side-track extending to the Southern Pacific car ferry on the Mississippi river, on the one hand, and into a belt line which returns by a 14-deg. curve, at the south, and an 8-deg. 21½-min. curve at the north, to the main line.

It will be noticed that space was left for additional tracks in the receiving division and that a 40-stall roundhouse, with cinder pit, coaling station and other necessary auxiliary facilities are located near by the exterior thoroughfare track. All the necessary accessories in the way of caboose tracks, wheel tracks, and car repair tracks were provided for, as shown. A gravity track for bad order cars branches from the main lead and runs parallel with the north ladder of the east distribution division. A plant for icing cars and a large transfer house were planned to be located north of the east gravity distribution tracks, and still north of these buildings there are stock pens and a set of outbound or north-bound departure tracks 2000 ft. in length, with a capacity of 500 cars. North-bound trains pass into the receiving tracks and through the distribution tracks in the same way as the south-bound traffic and are then assembled into trains on the departure tracks for the road engines. At the outlet of the departure tracks there is a set of caboose tracks, from which the caboose is picked up just before the train leaves the yard. West of the departure tracks, there are ten stub tracks constituting a sorting set, for arranging cars in "district" or station order. All the tracks arranged in sets are laid 13 ft. c. to c. The total length of tracks as planned is 48 miles and the capacity 3600 cars. The two-story office building is located at the head of the gravity lead, and opposite the same there is a hotel built and furnished by the railroad company.

A interesting example of a "hump" gravity yard on an extensive scale is the Chicago Clearing Yard, operated by the Chicago Union Transfer Ry. The general purpose of the yard is to accomplish for railroad freight traffic entering and leaving Chicago a service corresponding to that which a clearing house does for the banking business of a large city. The interchange of freight cars between the 20 and more roads is carried on over belt lines, and it is evident that with these cars collected at one point they can be distributed to the various roads, already made up into trains, with fewer switching movements than would be necessary if transferred direct by the belt-line crews making the rounds of the numerous terminal yards. In the clearing yard the switching is done once for all, economizing in switching movements and expediting the delivery of the cars. The cars set out at the terminal yard of each road for delivery to other roads are taken to this clearing yard, in any order in which they may happen to be made up, and there are distributed to the various roads and arranged in such order as the receiving road may desire, as, for instance, loads and empties, division, or other order.

A general plan of the yard reduced to convenient size, but not drawn to scale, is shown as Fig. 214 A. The yard extends east and west, connecting with the Chicago & Western Indiana R. R. on the east and with the Chicago Terminal Transfer R. R. and the Chicago Junction Ry. on the west, occupying a tract 13,000 ft. long and about 670 ft. wide. It contains 105 miles of track, with sufficient vacant space conveniently located for 25 miles of additional overflow and storage tracks, and, when built, was the most extensive system of yard tracks ever constructed at one location. The yard is far removed from the built-up section of the city and is not crossed by any public thoroughfare. All the connecting roads above named are belt and switching lines of Chicago. Although the primary object in the establishment of the yard was to provide facilities for receiving and forwarding cars with the utmost dispatch, the possiblities in the way of future extensions for the accommodation of such auxiliaries as naturally attach to railway terminals has not been overlooked. In the vicinity of the yard the company owns 3700 acres of land, intended to meet the space requirements of manufacturing establishments, grain elevators, storage warehouses for general merchandise, coal etc.; or for the duplication of the present clearing yard as a unit. The connection of the yard with the two belt lines at the west end has been laid out with a view to joining with a similar parallel yard lying immediately north. It is not improbable that this clearing yard may be found a desirable location for the temporary storage of cars of grain and other produce awaiting reshipment at the call of the markets, and when the demand for such storage facilities materializes, the necessary tracks can readily be added to the yard, as now laid out.

Extending along both north and south boundaries of the yard for the whole distance east and west there are three thoroughfare tracks with double-track "Y" connections at each end to the belt lines. At the center of the yard, from north to south, and near the east end, is located the engine house, and from this engine house, running straight west on the middle line of the yard, is a through track known as Track No. 25, which is referred to in connection with the switching movements. At the west end this track and the three outer tracks on each side of the yard merge into a double track which makes a "Y" connection with the Chicago Junction Ry. and the Chicago Terminal Transfer R. R. The general arrangement of the layout consists in two sets of distribution tracks (*B* and *B′*) each 2400 ft. long, extending the full width of the yard and leading from double ladders on either side of the artificial gravity mound, with receiving tracks (*C* and *C′*) 1600 to 3200 ft. long symmetrically arranged north and south of the gravity mound. East and west of the distribution tracks there are overflow tracks (*D* and *D′*) running parallel with the distribution ladders, intended for use in case the distribution tracks become filled. To the west of the west distribution tracks (*B′*) a large amount of space has been reserved for storage tracks, repair tracks, icing houses and like facilities. The number of parallel tracks in a north and south direction is 49, occupying a space 660 ft. wide. The spacing of the distribution and receiving tracks is 13.3 ft. center to center, and of the thoroughfare tracks on the outside of the yard, 14 ft. and 15 ft. c to c, respectively, progressing outward. Parallel with the double ladder at the mound end of each distribution set there are two tracks, the one next the ladder being a poling track and the outside one a drilling track. The double ladders of each distribution set converge at a three-throw switch into track No. 25, so that over the summit of the gravity mound there are five parallel tracks, with leader tracks and crossovers as shown. The gravity mound or "hump" is 5000 ft. long. For a short distance each side of the summit there is a grade of $1\frac{1}{2}$ per cent, arranged to start the cars quickly from the summit, and then a long grade of 0.9 of 1 per cent for a distance of 1900 ft. running into a grade of $\frac{1}{2}$ of 1 per cent for a further distance of 350 ft. The foot of the gravity lead is something like 400 ft. beyond the ends of the distribution ladders. The summit of the gravity mound is 22 ft. higher than the elevation of the level tracks of the yard. As protection against wind and wash from rains, the side slopes of this mound are covered with a layer of cinders, in some places, and in other places with riprap stone.

The arrangement of the yard permits of a flexibility of operation that is remarkable. Trains approaching from one of the "Y" connections at either end of the yard are run into one of the receiving tracks, where the power is detached, taking a return load from one of the distribution tracks in B or B', by way of one of the outlet ladders of the distribution tracks. A switching engine of the clearing yard then takes the train, backs up, and pushes it over one of the drilling tracks alongside the distribution ladder. In continuation of each of these drilling tracks there is a leader extending across all five of the parallel tracks over the gravity mound. This leader connects with each track by means of a slip switch. As the train is pushed up the summit the couplers are disconnected between each cut of cars, and as the cars go over the summit they separate from the train and run into and down track No. 25 to the three-throw switch at the apex of the distribution ladders, where they are switched to either side of the double ladder, and finally into the desired track of the distribution set. By means of the leader on either side of the summit, switching can be carried on simultaneously with two engines, in both directions; that is, into both the east and west distribution tracks. Each train of cars to be split up is pushed over the mound and distributed to such roads and sub-classifications as would naturally be taken out of the set of distribution tracks into which they are first dropped. The cars which would naturally be taken out of the opposite set of distribution tracks (east or west of the summit) are dropped to one or more tracks specially designated for that purpose, until a string accumulates, when they are pushed back over the hill and classified into the other set of distribution tracks. It is thus seen that by two switching movements, at most, trains of cars for any number of roads can be arranged in desired order. The capacity of the yard is 5000 to 8000 cars switched and forwarded daily.

The purpose of the poling track between each distribution ladder and the parallel drilling track, is to permit the assistance of an engine in case the cars should stop short, owing to heavy winds opposing the movement of the car under gravity, extreme cold weather or snow. It is known that such causes, particularly hard, opposing winds, are some of the difficulties attending the operation of gravity yards. As this yard is arranged, however, adverse winds can never operate to the disadvantage of switching in more than one direction at a time; for, when blowing against the switching of cars to the westward, for instance, the direction of the wind will then be with the movement of the cars that are being switched toward the east, thereby assisting the action of gravity. The arrangement for returning the brakemen who ride the cars down the gravity tracks consists of a light engine and car running forth and back on either the center track or on one or both of the poling tracks. On the tracks near the middle the first cars which are dropped down from the summit are stopped a short distance beyond the ladder connection, and then dropped further down, from time to time, as cars accumulate on that track. By this arrangement a few men can easily attend to dropping cars down, so as to leave room at the head end, and thus fewer men are required to brake the cars down from the summit. On the tracks at the sides of the distribution groups, whereon there is a considerable stretch of level, the men catch the cars at the lower end.

In this yard there are approximately 450 switches, and of these the 120 switches along the ladders of the distribution tracks are operated by Westinghouse electro-pneumatic cylinders. The design of these cylinders is similar to that of the standard machines of that type for interlocking work (Fig. 225), with the exception that the central or lock magnet is omitted. The control of the switches is by means of electric push-button machines in an operating cabin arranged upon a bridge standing over the summit of the gravity mound. The cabin is 30 ft. above the track and the span of the bridge supporting it is 68 ft. From this cabin there is an unobstructed view of the yard from end to end, or for a distance of two miles in both directions. For the 120 switches there are 10 push-botton machines, each machine controlling the movement of 12 switches. A similar installation is in service in a yard of the Pennsylvania R. R., at Altoona, Pa., as already described. For convenience of night work the gravity tracks are lighted by arc lights arranged on poles at intervals of about 300 ft., at the sides of the distribution ladders. These lights are shaded on the side toward the operating cabin. This arrangement permits the light to be thrown straight ahead into the distribution tracks, but protects the eyes of the cabin men and of the brakemen riding cuts of cars, from the direct rays. The switch lamps are lighted by incandescent electric lights of 8 candle power, as described in the section on switch lamps in this chapter (§ 66).

Figure 214A shows the location of the engine house, near which is the coaling station; the power house, for lighting, air compressing and pumping; the yard office and the operating tower. The water supply for the yard is forced from artesian wells by compressed air into an underground concrete reservoir, from which it is pumped into a tank of 100,000 gals. capacity, built on a tower 62½ ft. high standing between the office building and the power house. From the tank there are lateral pipes running to each side of the yard, where they connect with mains running the whole length of the yard and supplying 15 water cranes. Altogether there are 12 miles of water mains throughout the yard. The connection between the tank and these mains is such that in case of fire the tank valve can be shut off and direct pressure can be put upon the mains through fire pumps in the power house.

The drainage of this yard and the construction of the roadbed for the tracks are also interesting features. The surface of the land on which the yard was located was smooth and practically level, no part being 2 ft. higher than the general contour. This fact, taken in connection with the flat country surrounding the yard for a long distance, made it desirable to provide an extensive drainage system. Running westward along the north side of the yard there is a main sewer, with lateral sewers every 600 ft. The main sewer begins at the extreme east end of the yard, and for the first half mile it consists of 18-in. vitrified pipe, where it enlarges into a 27-in. vitrified pipe for the next half mile, and then into a 36-in. concrete sewer for the next mile, then a 48-in. concrete sewer for ½ mile, and for nearly all the remaining distance out of the 4½ miles there is a concrete sewer 7½ ft. in diameter, with a shell 1 ft. thick. The section of the concrete sewer in each case is circular and the figures refer to inside measurements. The sewer falls 30 ft. from end to end, or in a distance of 4½ miles, and its depth below the surface is 6 to 25 ft. At the west end of the property it empties into an open ditch which drains into the Illinois & Michigan canal. At this point the sewer is arch shaped, the span of the arch being 9 ft. and the hight from the bottom of the sewer to the crown of the arch about 7 ft. The vitrified pipe of the lateral system of sewers is 8 to 15 ins. diam. and the aggregate length of lateral sewers is 12 miles.

The grading of the roadbed or the foundation of the yard tracks consisted in depositing a 2-ft. layer of sand over the entire area enclosed by the tracks—a strip of land about 670 ft. in width and 2¾ miles long. In this shallow fill there was deposited 1,200,000 cu. yds. of sand, and in the gravity mound 400,000 cu. yds. additional. Over the sand there is a 6 to 8-in. layer of broken slag serving as a sub-ballast. On this the track was laid and ballasted with gravel in some places and cinders in others. For leveling off gravel unloaded from the cars for ballasting purposes a car with winged scrapers was used. The tracks were laid with new 75-lb. rails. In the thoroughfare and gravity tracks the ties are oak, while in the receiving tracks and on the level portion of the distribution tracks they are of cedar, laid 2800 to the mile. A full description of the yard, with numerous illustrations, was published in the Railway and Engineering Review for Nov. 16, 1901.

82. Machine Operation of Switches.—At points where switching movements are frequent or numerous, and especially if it is desired that the switching shall be done without stopping the trains, as at the end of double track, at junctions and in busy yards, it is customary to employ regular switch tenders. If a number of switches are near together one tender may be able to operate all of them, but if they extend beyond the

Fig. 218.—Typical Switch and Signal Tower of American Railroads.

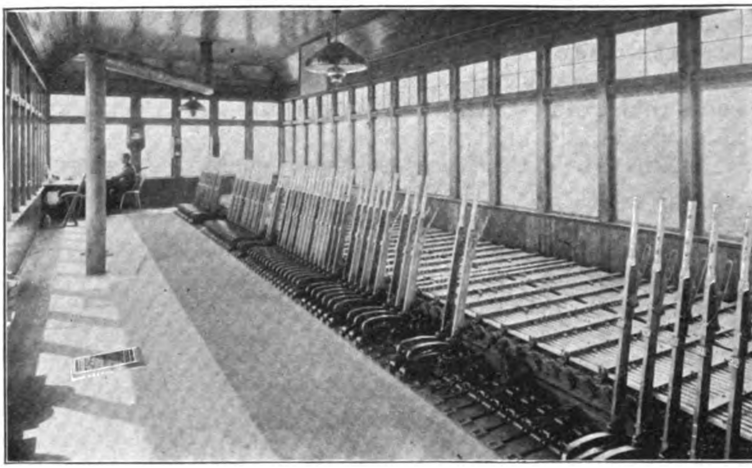


Fig. 219.—Interior of Signal Tower, Showing Interlocking Machine.

limits of convenient running distance, economy of time in the movement of the trains may require either more than one tender or that the means for throwing the switches be concentrated at a central point where the attendance can accomplish more efficient service than would be possible by running from stand to stand among switches widely separated. The latter alternative calls for machines operated at or from a distance. These machines, or the means for controlling the same, are usually assembled in the high second story of a switch or signal tower located in some commanding position where a view of the tracks may be had over the tops of cars, and unobstructed by other buildings. Figure 218 fairly illustrates a typical switch and signal tower, the intention of the closely placed windows extending entirely around the building being obvious. As the operation of main-line switches from a tower is in connection with interlocked signals, the two are usually considered together. In a comparatively few instances, however, as in yards, switches are thus operated without interlocking, and for the purpose of an elementary treatment, which is all that is here intended, it will conduce to clearness to take up the two subjects separately, referring first to the several types of mechanism for throwing switches, and their manner of operation, and then following on to the fundamental principles and appliances of interlocking.

Devices for throwing switches at a distance are of two general types, namely, hand machines and power machines. The hand machine consists of a lever or number of levers with pipe-line connection to the switches, 1-in. pipe being the size commonly used. These levers are pivoted to a frame and are spaced closely side by side, so that a large number can be placed within the distance of a few steps of the towerman. The levers of a machine, commonly known as a "mechanical interlocking machine," resemble very much the reverse lever of a locomotive, as will appear from Fig. 219, which shows the interior of an interlocking tower. The line of pipe connecting with each switch is carried on roller bearings mounted upon supports 7 or 8 ft. apart, known as "pipe carriers," and change of direction is by means of bell cranks. To automatically adjust the line of pipe for expansion and contraction due to change of temperature, the pipe is cut at intervals and compensating devices are inserted. A simple device for this purpose is a rocker or straight bar, pivoted at its center and connected at its two ends with sections of the line. It is readily seen that expansion or contraction in either section of the pipe line is compensated by that in the other without affecting the adjustment of the line. This device reverses the motion of adjacent sections of the pipe line, and takes up considerable space, the latter feature being objectionable where there are several pipes running parallel. A compensator which continues the pipe in the same straight line, called by convention a "lazy jack," is shown in Fig. 220. It consists of two bell cranks of supplemental angles, pivoted to a base casting and united by a short link. In this way the direction of motion of the two halves of the pipe line is reversed, as with a rocker, and contraction and expansion are provided for. Bell cranks, if inserted between sections of pipe line approximately equal in length, in such a manner that the pulling of one section pushes the other, perform the function of compensators. For distances less than 100 ft. no compensator is needed and in long lines of pipe one compensator is usually provided every 400 to 700 ft. Switches are operated by pipe line as far as 2000 ft. from the tower, and sometimes farther, but such distances are unusual.

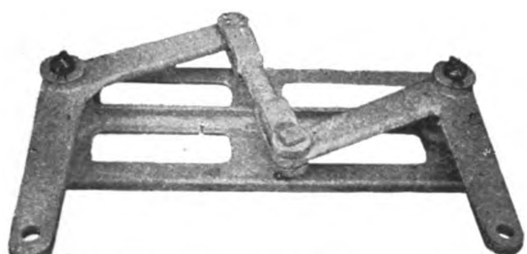


Fig. 220.—"Lazy Jack" Compensator.

Where switches are thrown from a tower there is not opportunity for the man at the levers to learn from observation, at every movement, whether the point rails have made a full stroke. As a safeguard in operating main-line switches in this manner it is therefore necessary to have some means for testing the action of the switch, so as to make known any defective working of this kind. This check upon the reliability of the switch movement is by means of a device for locking the switch in each rest position, which acts or refuses to act according as the switch works properly or improperly; it also serves the purpose of a double connection to hold the switch firmly to position under train movements. Of locks for this purpose there are two arrangements, the distinction depending upon the fact as to whether the device is actuated by the same lever that throws the switch or by a separate lever. The facing-point lock is of the latter class. It consists of a flat lock rod attached to the switch points and working through a slotted casting, and a bolt or plunger operated from the tower and working through the same casting at right angles to the lock rod, as shown in Fig. 221. In the lock rod

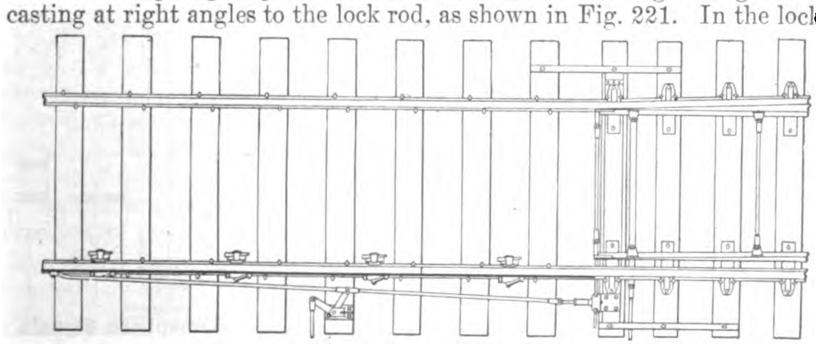


Fig. 221.—Facing-Point Lock, Outside Connected.

are two holes, corresponding to the closed and open positions of the switch, and when the point rails are in proper adjustment the plunger registers with one of these holes for each rest position of the switch. Before the switch can be thrown from either rest position the plunger must first be withdrawn, and should the point rails not move entirely home the registration of the plunger will be obstructed by the solid metal of the locking bar, making it impossible to throw the lock lever in the tower, thus indicating that the switch is out of adjustment and in need of immediate attention. As is explained more in detail in the following section, the switch and lock levers are interlocked with the signal lever, and the sequence of operation is such that if the lock fails to work, the signal must remain at danger until the switch is properly adjusted. The lock shown in the figure is known as the "outside" pattern, taking its name from the position of the plunger casting. With an "inside" facing-point lock the plunger casting is secured to the same tie, in the middle of the track, and the locking takes place at the middle of the tie bar instead of on an outside extension of the same.

By the "switch and lock" movement the lock and switch are thrown by the same lever. The arrangement is shown in Fig. 222. Instead of connecting the throw rod to the switch points direct it is made to actuate an escapement crank (*A*), otherwise called the "switch crank." By this means there is, at both the beginning and ending of the stroke, about 2 ins. of dead motion in relation to the switch, which unlocks the switch before the point rails are acted upon and locks them up after they have moved to place. Briefly described, there is a base casting with guides for the throw rod or driving bar and for the lock rod. The driving bar consists of two straps bolted to end pieces so as to straddle the escapement crank. The engage-

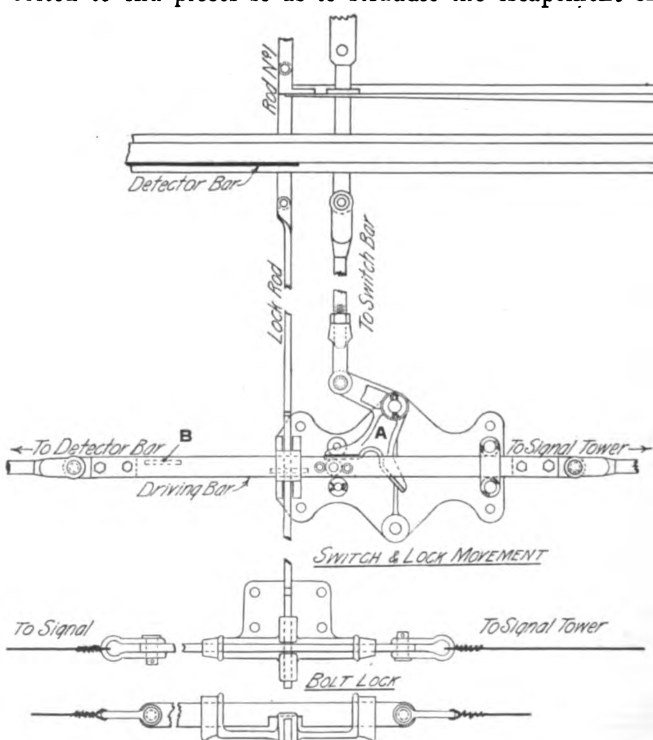


Fig. 222.—Switch and Lock Movement and Bolt Lock.

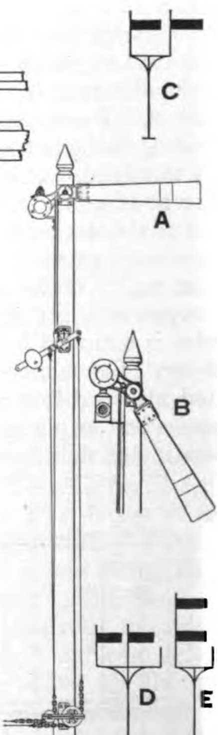


Fig. 223.—Semaphore Signals.

ment with the escapement crank is by means of an operating roller carried between the two straps of the driving bar. The driving bar and lock rod cross each other at right angles, there being a locking stud or lug (*B*) on the former to fit a corresponding notch on the lock rod for each position of the switch. On some patterns other than that shown the locking is by means of locking pins on the driving bar fitting corresponding holes through the lock rod. The full stroke of the driving bar is 8 or 9 ins., and the manner of operation is as follows: During the first 2 ins. of the stroke the locking stud is withdrawn, releasing the switch, but as the operating roller travels parallel with the arm of the escapement crank against which it bears there is thus far no tendency to move the switch. The operating roller next meets the other arm of the crank, swinging it some 4 or 5 ins. and throwing the switch. During the last part of the operation the roller again moves parallel with the crank arm against which it bears, a further distance of about 2 ins., bringing the locking parts into engagement after the motion of the switch points has ceased.

As the switch and lock movement dispenses with one lever for each switch, it effects an important economy in apparatus and in the number of movements, and consequently time required, to operate the switch, but in mechanical interlocking the use of facing-point locks on the important switches seems to be the preferable practice. In the switch and lock movement the travel of the parts is so slight (only about 1½ to 2 ins. in the throw rod) during the locking operation that by springing the connections in the case of a long pipe line it is sometimes possible to get the lever over when the lock refuses to work. As with the facing-point lock the stroke of the plunger is 5 or 6 ins., and some 4½ ins. past the lock rod, it is impossible with this device to throw the lock lever when the plunger will not enter the locking hole. A safeguard in the case of the switch and lock movement is the use of a bolt lock, described in the following section, in connection with interlocking. In the switch and lock movements of the Chicago, Milwaukee & St. Paul Ry. the driving bar has a stroke of 12 ins., with 3 ins. of locking travel at each end, which is supposed to be sufficient to prevent the latching of the lever when the locking movement is obstructed by misadjusted switch points. This lengthening of the driving bar stroke decreases the leverage. As with derailing switches it is necessary to lock the point rail only in the closed position (unless operated on the same lever with the lock for a turnout switch), the 3 ins. of locking travel may be obtained with a total travel of only 8 or 9 ins. in the driving bar. An interesting discussion of these matters was presented before the Railway Signaling Club in September, 1896, by Mr. W. H. Elliott, then signal engineer, Chicago, Milwaukee & St. Paul Ry. (See the Railway Review for Sept. 26 and Nov. 21, 1896, pages 536 and 650).

As the switch tower is necessarily somewhat removed from many or all of the switches, it is necessary, in order to facilitate rapid switching movements, to provide some device which will prevent the switch being thrown under a car or train. This device is known as the detector bar, shown in Fig. 224. It consists of a flat bar *A*, somewhat longer than the longest distance between car wheels (usually 45 or 50 ft.), which is held in position against the outside of the rail head by links *B*, pivoted to clips *C* attached to the rail as shown in the end elevation. There are lugs on the clips which limit the movement of the links and prevent the bar from getting out of adjustment. The bar is connected with the switch movement (or lock movement, in the case of a facing-point lock, as in Fig. 221), so that before the switch can be moved the bar *A* must be swung on the arcs described by the radial movement of the links about the pins of the clips

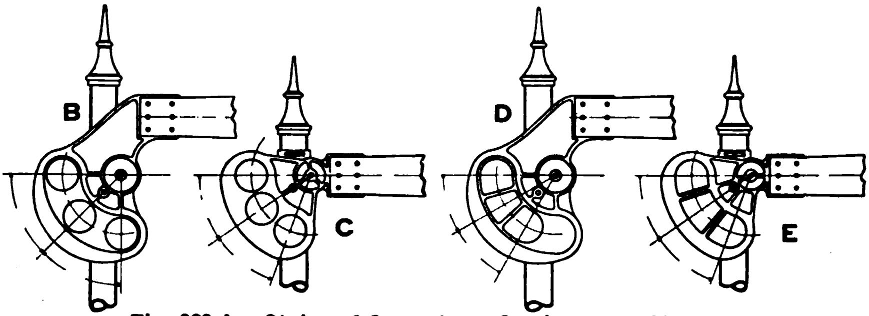


Fig. 223 A.—Styles of Semaphore Castings and Glasses.

as centers. As the bar is held but slightly below the top of the rail it must be raised about one inch above the rail in order to pass through one half of its stroke. If a wheel be resting on the rail at the bar it is obvious that the bar cannot be moved in the manner described, and, being interlocked with the switch or lock bar, no movement of the switch can take place. The operator in the tower can therefore grasp the lever while the train is moving over the switch and make ready to throw it the instant the wheels pass the detector bar, without fear of throwing it too soon. The detector bar is usually placed on the facing side of the switch. If placed on the trailing side two bars are necessary—one on the main track and one on the turnout —so as to protect the switch against a train on either track.

In power machines for throwing switches either one or both of two agents are employed, namely compressed air and electricity; and of these machines there are three systems, namely, the electro-pneumatic, in which the switch cylinder is operated by compressed air controlled by electricity; two patterns of pneumatic machines operated and controlled by compressed air; and an electric machine which is operated and controlled by electricity. Some of the advantages claimed for power machines are that they are more compact than hand machines, affording a closer concentration, which permits of smaller towers in large installations, and less attendance upon operation; that track room is not occupied by the connections between tower and switches, and as movable connections are not employed there is none of the

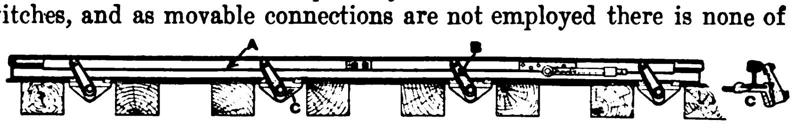


Fig. 224.—Detector Bar.

difficulties incident to the settlement of filled ground; that pipes for compressed air and insulated wires for electric currents can be laid farther than pipe lines can be readily worked; that over long distances the connections with the power machines are cheaper; and where there are complicated switches, crossings, sharp curves, etc., the connections are not only cheaper but far less complicated and less liable to derangement, as they can be buried up out of sight, where they will be secure from accident or molestation; and that fewer levers are required in the tower, thus reducing the expense of large installations and decreasing the time of operation. The last-named advantage is due to the fact that the number of mechanisms which can be operated simultaneously from one lever is limited only by the restrictions imposed by traffic requirements, whereas in the mechanical system—that is, by hand operation—the physical energy and endurance of the operator measures the capacity of each lever.

The Westinghouse electro-pneumatic operating mechanism as applied to a simple switch is shown as Fig. 225. The switch cylinder is 5 ins., and sometimes 6 ins., in internal diameter and the stroke of the piston is 8 ins.

The air for operating the cylinder is piped to it at a pressure varying in different installations from 45 to 80 lbs. per sq. in., but usually about 65 lbs. per sq. in. Under the cylinder there is a small auxiliary reservior to receive the condensation from the moisture in the air. The control of the valve for admitting air against the piston is by means of three electro-magnets secured to the side of the cylinder and operated on electric circuits connecting with the interlocking machine in the signal tower. The functions of these three magnets for a single movement of the switch are as follows: The middle one of the three magnets operates a lock which controls the movement of the valve admitting air to the switch cylinder. The other two magnets operate pin valves controlling the admission of air to and exhaust from two small auxiliary cylinders secured to the side of the switch cylinder, the pistons of both of which operate upon the slide valve which admits and discharges the larger volume of air used by the switch cylinder. The mechanism of the lock magnet device consists of a plunger, applied normally by a coiled spring which forces it into a recess in the slide valve, and which is withdrawn by exhausting the air from above the plunger piston by means of a magnetic pin valve, thus permitting the full pressure in the valve chamber to overcome the spring and force out the bolt. By de-energizing this magnet, which takes place as soon as the slide valve has moved, the exhaust passage operated by the pin valve is closed and the pressure, being admitted through a small leak hole through the piston of the plunger, gradually equalizes on both sides of the piston and permits the action of the spring to again lock the slide valve. In operation this lock must be withdrawn before the slide valve can be shifted to admit air to actuate the switch cylinder. The electrical contacts of the switch lever on the machine in the tower are so arranged that the three magnetic valves of the switch mechanism are operated in proper sequence to withdraw the lock previous to each attempt to shift the valve. In setting a switch the operator in the signal tower throws a lever (Fig. 235) through a portion of its stroke, making electrical contacts with circuits connecting with the valve magnets on the switch cylinder. The first movement, as previously stated, is the action of the pin valve of the lock magnet, which operates to unlock the slide valve, and this slide valve is then acted upon by air pressure controlled by

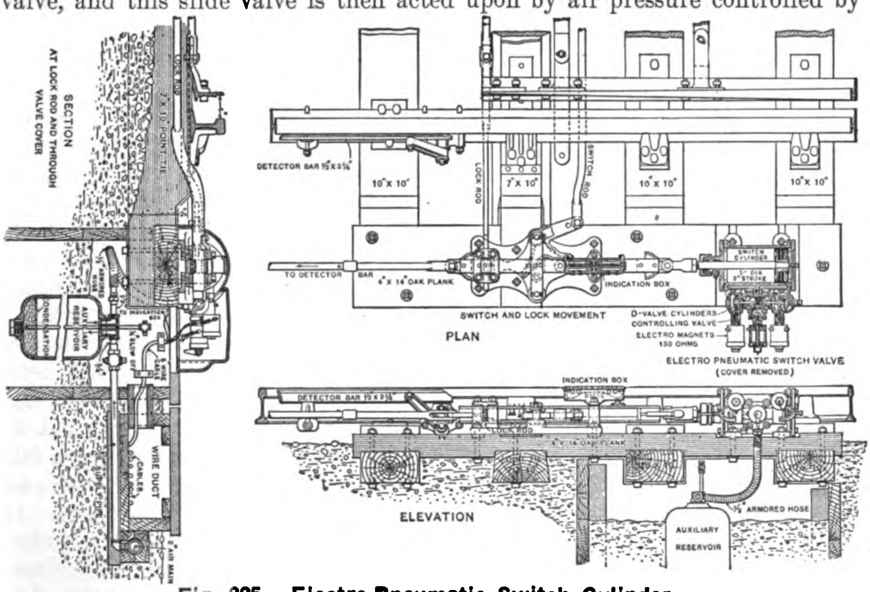


Fig. 225.—Electro-Pneumatic Switch Cylinder.

the movement of the pin valves in the outside electro-magnets. The movement of the lever beyond the point where the lock magnet is actuated discharges one of the valve magnets, permitting the air to exhaust from the auxiliary cylinder controlled by that magnet, and energizes the other valve magnet, admitting air to the auxiliary cylinder on that side and forcing over the piston which works the slide valve. The movement of the slide valve admits pressure against the piston of the switch cylinder, the piston rod of which is connected with the switch and lock movement and the detector bar shown (Fig. 225).

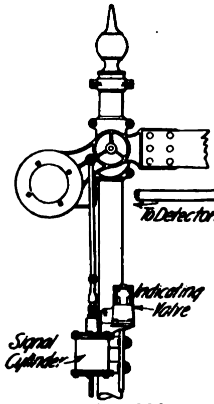


Fig. 226.

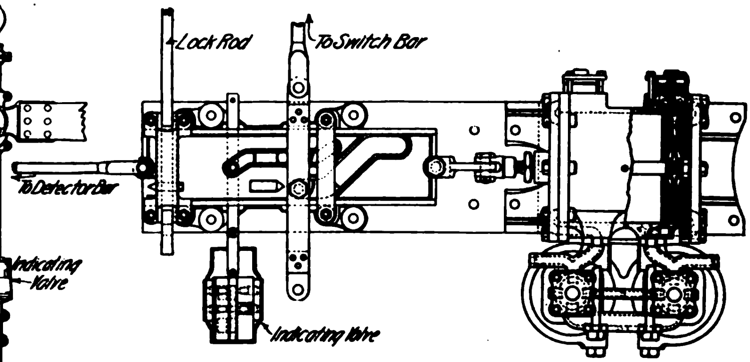


Fig. 227.—Switch and Lock Movement for "Standard" Pneumatic System.

In operating switches from a tower it is necessary that some indication be received by the operator to assure him at each movement that the switch has properly completed its stroke. With the hand machine the indication of a failure of the switch to complete its throw is given by the refusal of the locking lever to make the full stroke. The indication with the electro-pneumatic mechanism lies in the ability to complete the throw of the operating lever in the signal tower. When this lever is first manipulated for moving the switch it is thrown up against a stop, making only a partial movement, as stated. The position of this stop is controlled by an electro-magnet on a circuit operated in connection with the locking device of the switch mechanism. If the switch has been thrown to proper place and locked a contact is made which causes the electro-magnet in the signal tower to withdraw the stop, permitting the lever to be given its full movement, thus indicating to the operator that the mechanism at the switch has properly performed all of its functions. If the stop is not withdrawn the stroke of the lever cannot be completed and the signal lever is locked in the danger position, as explained farther along.

The "Standard" apparatus for throwing switches is controlled, operated and indicated by air pressure. The pressure for the controlling and indicating movements is 6 lbs. per sq. in. and that for operating the switches is 20 lbs. per sq. in., the difference in pressure being obtained by means of reducing valves. This is known as the "low pressure pneumatic" system. The operating bars or "levers" of the interlocking machine (Fig. 237) are straight steel bars with upright handles, pulling straight out to the front. The manipulation of a lever for a switch movement is as follows: The lever is first pulled out about half its stroke, where it stops and air is admitted to the controlling pipe running to the switch cylinder. It there operates a valve which admits air against the piston of the cylinder. The movement of the switch points operates apparatus sending an indication current of air back to the machine in the tower, and this indication current completes the stroke of the lever. This automatic completion of the stroke of the lever is the "indication." The switch and lock movement of the Standard system is by means of a "motion plate," as shown in Fig. 227. This device is a sliding plate attached to the piston rod of the switch cylinder, and the means for imparting motion to the bar connecting with the switch points is a diagonal slot, and an operating roller attached to the switch connection. The two ends of this slot are parallel to the direction of movement of the motion plate, the purpose of which is to utilize the beginning and ending of the stroke, severally, to unlock and lock up the switch, as only the diagonal portion of the slot can operate to impart side motion to the bar connecting with the switch. The indicating valve is operated by a slot in a similar manner, the parallel part of this slot corresponding to the diagonal part of the slot operating the switch. The working of the locking mechanism is apparent from the illustration, it being observed that the slot operating the indicating valve is so arranged that it cannot actuate the valve rod until the locking stud engages with the notch in the locking rod.

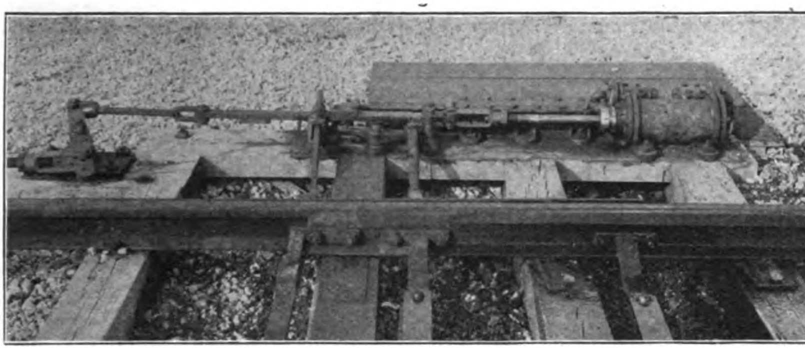


Fig. 228.—Thomas Pneumatic Switch Cylinder, N., C. & St. L. Ry.

In the Thomas pneumatic system for handling switches and signals the movements are controlled, operated and indicated by compressed air. It was designed by J. W. Thomas, Jr., general manager of the Nashville, Chattanooga & St. Louis Ry., on which road a number of installations of the system are in service. The distinctive feature of this system is the working of the valves admitting air to and exhausting it from the switch cylinder by means of pistons of the equalizing type, which are actuated by a sudden increase or decrease of the air pressure on opposite sides of the piston. Secured to the switch cylinder (Fig. 228) near each end there is an air chest in which is a valve controlling the admission and exhaust of the air to and from that end of the cylinder. Each of these valves is in pipe connection with a pressure-controlling valve operated by a lever in the signal tower (Fig. 229). In these two pipes leading to the switch mechanism there is a difference of pressure of 10 lbs. per sq. in., the pressure in one of them being 70 lbs. and that in the other 80 lbs. per sq. in. In the switch cylinder, under the normal condition of things, there is a pressure of 80 lbs. per sq. in. on one side of the piston, with the other side open to the atmosphere. When it is desired to throw the switch a lever is pulled (half stroke) in the signal tower, which operates a controlling valve, increasing the pressure in one of the controlling pipes from 70 to 80 lbs. per sq. in. and decreasing it in the other (by exhaust into an empty reservoir) from 80 lbs. to 70 lbs. per sq. in. This change of pressure shifts the valves on the switch cylinder, admitting air at 80 lbs. pressure to one side of the piston and exhausting it from the other, thus operating to throw the switch.

Through the piston of each valve at the switch cylinder there is a small leak hole, which permits the pressure to equalize on both sides of the piston soon after it has been actuated by a sudden change of pressure in the controlling pipe. By this arrangement the conditions are always such that the valve piston is in readiness to act at the next change of pressure, be it an increase or a decrease; in fact action will take place without waiting for the pressure to equalize. To increase the capacity of the air supply, so as to move the valves quickly, there is a small reservoir under each end of the switch cylinder, in communication with the valve chest on that end. In connection with the switch operating mechanism there is an "indication chest" in communication with a valve on the interlocking machine in the signal tower through two pipes in which the pressure stands at 70 and 80 lbs., respectively, as in the controlling pipes.

The operation of the switch is by switch and lock movement, and on the driving bar of the same there is an arm which works the indication chest. As soon as the switch points have been thrown fully up this arm comes into engagement with the stem of the valve in the indication chest,

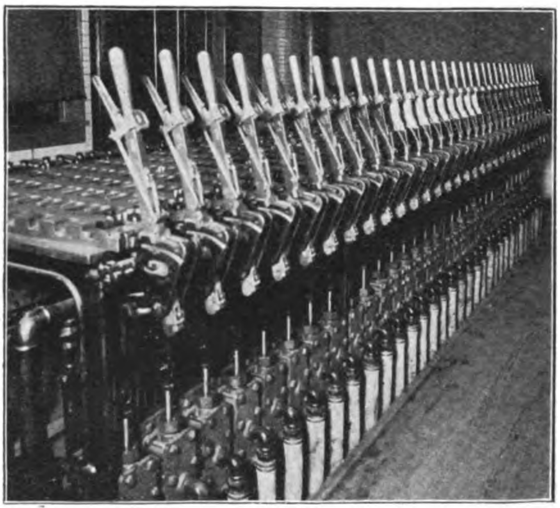


Fig. 229.—Interlocking Machine of the Thomas Pneumatic System.

the shifting of which throws ports into connection which reduce the pressure in one of the indicating pipes from 80 to 70 lbs. per sq. in. and increase it in the other from 70 to 80 lbs. This alternation of the pressure operates the above-mentioned valve on the interlocking table, which withdraws a stop pin, releasing the operating lever and permitting the completion of its stroke. Until this indication is received, by the response of the switch, the lever cannot be thrown from the midway position of its stroke, where it was stopped as soon as the controlling valve had been shifted to throw the switch. In Fig. 229 the controlling valves appear at the front of the interlocking machine, directly under the levers. The time consumed in operating a switch 250 ft. away, including the indication, is about one second; at a distance of 1000 ft. the time is 3 seconds. To give some idea of the rapidity of the movements a switch 250 ft. away has, by actual test, been operated 28 times per minute.

The Taylor switch machine, shown in Figs. 230 and 231 with the cover removed, is operated by an electric motor, the capacity of which for a single switch is about 1 horse power; but the power required is but little more

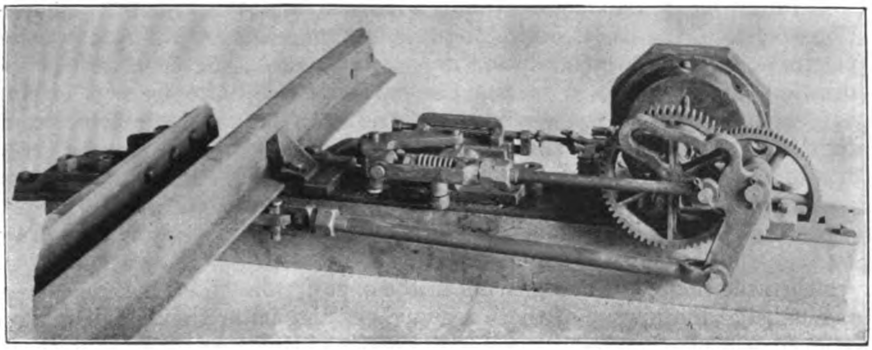


Fig. 230.—Taylor Electric Switch Machine (Switch Open).

than half of this, being usually 7 amperes at 60 volts. The current for operation is usually supplied by a storage battery in the signal tower, charged at intervals by a gasoline engine and small dynamo, or from some other source of electrical energy. In throwing the switch a bar or "lever" on the interlocking machine (Fig. 238) is pulled half stroke, closing a circuit which causes the motor to turn 20 revolutions in about two seconds, driving the train of gear wheels shown. Through this gearing the main driving wheel is revolved one revolution, actuating by means of a crank pin the cam movement which throws the rod connecting with the switch points. The switch lock is operated by a rod connected to the crank pin of the main driving gear, this rod appearing just above the switch connecting rod, in the picture. This rod acts upon the lock bolt through a bell crank and withdraws the bolt from the lock rod before the switch connecting rod begins its stroke. After the stroke of the switch is completed the lock bolt is reinserted. The movement of the lock rod compresses a spiral spring encircling the rod of a pole changer. The final movement of the lock bolt releases this spring and its energy operates to reverse the pole changer, opening the driving circuit, reversing the armature connections and closing the indication circuit. In machines of later design the pole changer is operated by positive action, the power to do so being derived directly from the lock bolt, but is available only after the bolt has passed through the lock rod. This power is transmitted from the bolt to the pole changer through a pivoted lever having a movable fulcrum, the same being moved by the lock rod to one side or the other of the pivot as the lock rod follows the movement of the switch point to one position or the other.

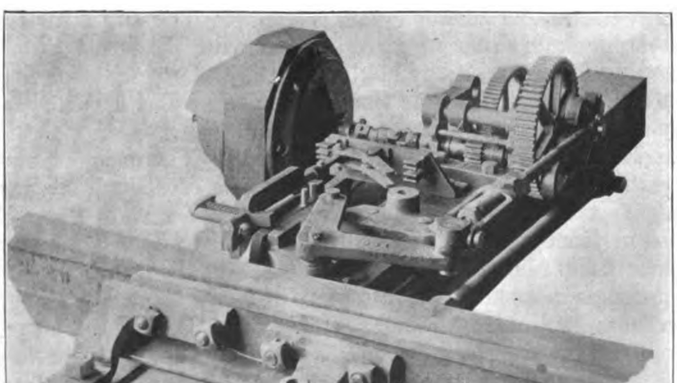


Fig. 231.—Taylor Electric Switch Machine (Switch Closed).

Immediately the motor circuit is broken and the armature connections reversed, the motor begins to act as a generator, setting up a counter electromotive force which opposes its own momentum and energizes the indication circuit. The indication current actuates electro-magnets on the interlocking machine, which release the lever and permit the operator to finish the stroke of the same. Hence if the switch is not moved fully home the lock bolt is obstructed, there is no indication, and the inability to complete the stroke of the lever shows that the switch is out of adjustment. The throwing of the switch in the reverse direction is accomplished by pushing the lever in the interlocking machine toward the normal position, which turns the motor and gearing in the opposite direction, the cam movements being the reverse of the foregoing. If the motor should fail to stop at the proper time it is automatically thrown out of gear. Where it is desired to operate a mechanical detector bar (Fig. 224) in connection with

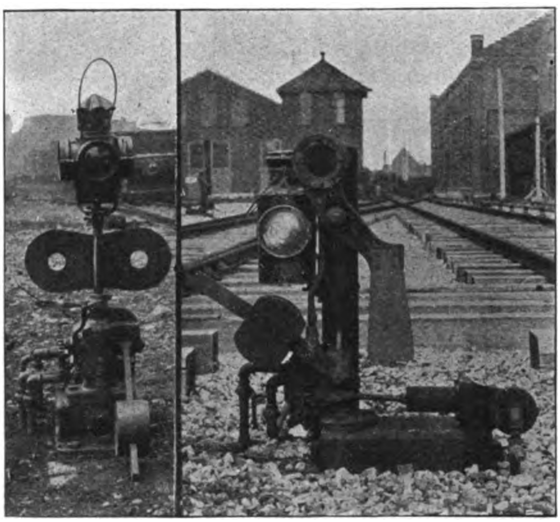


Fig. 232.—Dwarf Signals, Thomas Pneumatic Interlocking System.

this machine a T-crank is substituted for the bell crank to operate the lock bolt, and the detector bar connection is attached to the spare arm of the T-crank. In some installations of Taylor apparatus the dectector bar is dispensed with and a track circuit is made to serve the purpose. With this arrangement the closing of the track circuit by the presence of cars opens the battery circuit leading to the switch machine. The two figures are views of the machine from different directions, showing the positions of the parts corresponding to two positions of the switch. At Bridge Junction, Ill., on the Illinois Central R. R., near the long Cairo bridge, a switch is operated by a Taylor machine that is 5300 ft. from the tower.

83. Interlocking Switches and Signals.—The most common form of railway signal is the semaphore, which consists of a blade or arm pivoted to a post or pole so as to show on the front side and to the right of the same as seen from approaching trains governed by it. Semaphore signals are of three kinds: home, distant and dwarf signals. In home and distant signals the semaphore arm is a thin piece of board about 5 ft. long, tapering in width from 10 ins. at the outer end to about 7 or 8 ins. near the pole. Home and distant signals differ in shape only at the end, the home signal having a square end, as in Fig. 223, and the distant signal a notched or fish-tail end, as in Fig. 245. In block signaling the end of the semaphore is sometimes pointed, to distinguish it from interlocking signals. These signals are usually placed at the top of a pole standing about 25 ft. high above the track, and wherever it is practicable the pole is located at the right-hand side of the track which the signal governs. The semaphore blade is bolted to a pivot casting called the arm plate, and the movement of the signal is by means of a vertical rod connecting this casting with a "balance lever" some distance down on the pole. This balance lever (Fig. 223) is usually worked by a pair of wires connecting with chains passing around pulleys at the foot of the pole and running to a lever in the signal tower. On some roads, however, it is the practice to operate home signals by pipe connection, in the same manner that switches are operated from mechanical plants. The balance lever is weighted on the longer arm so as to overbalance the semaphore blade and hold it in or pull it to the horizontal or normal position in case a wire should break. The arm plate casting is designed to overbalance the blade and bring it to normal in case it should become disconnected from the balance lever below. A ladder running to the top of the pole gives access to all the parts. The dwarf semaphore signal (Fig. 232) has a blade about 1 ft. long with a square end, and is placed on a low post at a hight of 2 or 3 ft. above the rail. As this signal is usually placed close to the track or between tracks that are close together its blade is usually made of thick rubber, so as to avoid injury in case it is struck by a passing object. Another arrangement is to hinge the blade to the arm plate and provide springs to return it to the straight-out position in case it should be knocked around by anything passing. Dwarf signals are used to govern movements from main track to side-tracks, movements from one side-track to another, yard movements; and movements on main line against the normal direction of the traffic, as, for instance, "back-up" movements on double track.

Home and dwarf signal blades are usually painted red (and sometimes yellow) on the face and white on the back, and the blades of distant signals green or yellow on the face and white on the back. As, however, the semaphore is a position signal its color is without significance, the idea being to select the color which is most conspicuous at a distance, in daylight, and then, to add to the distinctiveness, a bar is painted across the face of the signal in some color which bears a striking contrast, like white on red or green or black on yellow.

A home or dwarf signal blade in the horizontal position (*A*, Fig. 223) is an indication of "danger," and the engineer is supposed to stop and wait until the signal is changed. The blade of any signal (home, dwarf or distant) hanging vertical or obliquely downward (usually 65 to 75 deg. from the horizontal), as in Fig. 232, and at *B* in Fig. 223, is a "clear" indication and gives the engineer permission to go ahead at full speed. There is some difference in practice as to the exact position of the semaphore for clear, as on a few roads, including the Pennsylvania Lines West, the blade hangs vertically downward for this indication, while on the majority of roads, as above intimated, it stands out 15 to 25 deg. from the pole. The latter position is the preferable one, as the blade is more conspicuous when swung out clear from the pole than when hanging in close by its side. With the blade in the latter position the appearance of things bears too close a resemblance to a pole without a blade, and with enginemen habitually controlled by such a signal a pole with the blade broken off might easily be mistaken for a clear indication. Engineers accustomed to seeing the blade stand out clear of the pole for all indications would quite likely detect something wrong in the absence of the blade. On some roads there is a third position (the blade standing at an angle of 45 deg. with the pole, in some instances above the horizontal and in other instances below it) signifying caution, but such practice is unusual. As the purpose of the distant signal is to indicate the probable position of the home signal, the horizontal position of the former is an indication of "caution," and is a warning to the engineer to bring his train under such control that it can be stopped at the home signal in case it should be found at danger.

The night indications are by lights of different colors. The arm plate holds in rear of the pivot one or more colored glasses, called "spectacles," which are moved to stand in front of a lamp in correspondence with the signal positions of the semaphore blade. This lamp is designed on the style of a switch lamp and is placed upon a bracket so as to come within the sweep of the spectacle arm. In universal practice a red light is the night indication for danger, and hence on home and dwarf signals this is the color of the spectacle glass which covers the signal lamp when the blade is horizontal. On the majority of roads in this country the clear indication on home, dwarf and distant signals at night is a white light, in which case the spectacle arm carries only one glass (for a two-position signal), that being colored, of course. To show a white light in that case it is only necessary to swing the blade so that the spectacle casting will uncover the signal lamp. The corresponding indication for caution at the distant signal is a green light. Practice is gradually changing, however, to the use of a green light for clear at home, dwarf and distant signals, and a yellow light for caution at the distant signal, white light not being used for any signal. On the Chicago & Northwestern Ry. the home signal at night shows a red light for danger and a green light for clear. The distant signal shows a green light for clear and a combination red and green light for caution. This double light is produced by one lamp shining through two lenses—through one lens direct and through the other by reflection. The lamp carries green and white lenses, the green lens being outside the sweep of the spectacle arm. The upper ring on the semaphore casting carries a red glass, and when the blade is at caution this glass stands in front of the white lens of the lamp. The lower ring of the casting carries a metallic shield, and when the blade is at clear this shield covers the white light and leaves only the green light visible. This arrangement of lights was devised by Mr. E. C. Carter, chief engineer of the road.

The objection to a white light as a signal indication is the trouble likely to arise from a wrong indication due to the chance breaking of a spectacle glass, or to the liability of mistaking a street or house light for a signal light, particularly if the signal light in the vicinity has gone out. In any case engineers should make it a practice to observe whether the position of the blade corresponds with the lamp indication. Where a green light is used for clear, it is of course necessary to have two spectacle glasses for all two-position signals. In the back side of the signal lamp there is usually a small lens, the light from which shines through a blue glass when the blade is in its normal position, so that the operator can at night see one side or the other of all signal lights, and thus be able to tell whether they are burning. This blue glass is held in a back-light casting attached to the semaphore shaft, which runs through the pole or through a casting attached to the side of the pole.

An important question with semaphore signals is the night indication for positions intermediate between those for danger and clear. In times of snow or sleet or when rain freezes to ice, or in case of derangement of parts, semaphore blades will sometimes droop considerably from the horizontal position when set for danger. With a casting like that shown at *A*, Fig. 223, the blade might droop sufficiently to uncover the signal light, thus giving a clear indication. One way of preventing the display of a white light with the arm in an intermediate position is to attach a shield to the bottom of the back casting, so as to cover the light until the arm swings to the clear position. This scheme of protection is based upon the principle that the absence of a signal is a danger indication, but it is not an indication that can be relied upon, for unless the engineer knows precisely where he is he may not be aware of the situation. The same difficulty would arise, of course, in the case of a casting holding two colored glasses with a blank between. All trouble from this source is overcome by the use of what is known as the "continuous-light" principle of design. By this arrangement the back casting carries red glass to cover the sweep of the arm all the way from the danger to the clear position, so that a danger indication will be given until the signal is entirely clear. Engravings *D* and *E*, Fig. 223A, show castings designed for this purpose, the two top glasses in each case being red. Engraving *C* shows the same arrangement with round glasses. The casting shown in Engraving *B* is not designed on the continuous-light principle.

Where diverging routes are to be governed two blades are used on the same pole, generally 6 to 12 ft. apart, such being known as a "route signal." The upper blade is the signal for the superior or high-speed route and the lower blade the signal for the inferior or slower-speed route, as, for instance, where freight traffic diverges from the main passenger tracks. At junction points, or wherever there might be any doubt as to which route is the superior one, the upper and lower arms and lights are assigned to the routes they govern by bulletin notice. On some roads, one of which is the Delaware, Lackawanna & Western, the lower blade of a double-arm home signal is full size only where both of the diverging routes are for fast-speed trains; if one of the routes is for slow movements into sidings, yards, etc., a blade of dwarf signal size is used for the lower signal. In using a two-arm home signal on this road it is the practice to obscure the light on the lower arm when it indicates danger, so that red lights will not be displayed against high-speed trains the movements of which they do not control. The standard two-arm signal of the Chicago, Milwaukee & St. Paul Ry. has, for the diverging route, an arm of dwarf size about 10 ft. above top of rail, and 17 ft. below the arm for the high-speed main-line route. The lower light in its normal position is then blinded, so that the engineman of a high-speed main-line train will get a high signal for the high-speed route and will not have to run against the red light for the diverging route.

Owing to close spacing of tracks it frequently happens that the pole for a signal cannot be placed next the track which it governs, in which case a pole of extra hight is set to the right of all the tracks, or as far to the right as it may be convenient to go in order to find necessary standing room, and the signals for the tracks are then arranged on posts set upon a bracket or cross arm in the order of the relative position of the tracks. Thus, Sketch *C*, Fig. 223, shows the arrangement for signaling two tracks lying consecutively next the pole. In case one or more tracks intervene between the pole and the track or tracks to be governed by the signals which it carries, stub or bladeless posts are placed upon the bracket to represent the tracks which are not signaled, the relative position of the stub posts corresponding to the relative position of the tracks which intervene between the pole and the tracks to be governed by the signals on the bracket. Sketches *D* and *E* (Fig. 223) illustrate the arrangement. At night these stub posts carry blue lights to indicate their number and relative position. If the bracket extends to only one side of the main pole and carries only one signal post the indication is the same as though the signal was on a straight pole. Such an arrangement is sometimes employed to afford a better view of the signal. Where more than three tracks have to be signaled at the same point the usual practice is to erect a light truss bridge over the tracks and place the signals upon it, each signal directly over the track which it governs. Figure 233 is an illustration of this arrangement, the signal bridge being located over six parallel tracks at the entrance to a subway, with double-arm signals over the first, second and fourth tracks from the right. Through terminals where the tracks are closely spaced and all trains run at slow speed the use of dwarf signals for all the tracks, main and sidings, is a plan sometimes followed. Two advantages with this arrangement are that the signals are much cheaper than high semaphores and each signal can be placed just where it belongs, namely at the side of the track which it governs.

Fig. 233.—A Signal Bridge.

Having briefly described the mechanisms of different types and patterns for operating switches from towers, and the most ordinary arrangements of semaphore signals for controlling train movements, it is in order to explain the purpose of interlocking the switches and signals of a route or of two or more conflicting routes, and to describe a few of the simple applications of the same. To start with, it should be understood that a thoroughgoing treatment of the subject is not intended. On nearly all roads in this country the installation and maintenance of interlocking plants and connections are in charge of a department separate and distinct from that of the track; and the practice of railway signaling, as well as the appliances thereof, is so diversified that a separate volume is required to treat it comprehensively. There is, however, between the two departments some division of work and responsibility, and some of the applications of signaling and interlocking require alterations of the track construction, as well as special adjustments and attachments. Interlocking is now so extensively employed that men in charge of track should have at least a general knowledge of such installations and the operation of the same. The aim in the elementary treatment here presented is merely to cover that much ground.

The interlocking of a switch with one or more signals is an arrangement whereby the levers or other means for throwing and setting the same are so controlled that the signals cannot be cleared until the switch has been properly set and locked; and, conversely, so that the switch cannot be moved while any of the signals is indicating a clear route over the same: in short, a clear signal cannot be given contrary to the position of the switch. The scheme of operation in this simple case applies likewise to all the switches and signals of a route controlled from the same point or tower. Two or more tracks crossing each other at grade are said to be "conflicting" or "opposing" routes, because it is unsafe to permit trains on either route to run past the crossing unmindful of the movements on the other route or routes. Routes converging to a junction are also conflicting, because right of way over the junction cannot be given to more than one route at a time.

At unprotected grade crossings the only safe practice is to require all trains to stop before reaching the crossing. A signal much used for giving the right of way over crossings without requiring the train signaled to stop is a gate hinged to a post standing in the angle between the tracks. The gate carries a danger target for day indications and at night a red lantern, and is in charge of a watchman who gives the right of way by swinging the gate over the opposing track. In some instances the gate post is a high pole and the swinging of the gate is made to operate a signal at the top of the pole which indicates the position of the gate. One form of signal for this purpose is a cross arm pivoted at the middle. The normal position of the arm is diagonal, or at an angle of 45 deg. with the horizontal, which is a danger indication for both roads. The horizontal position is a clear signal for one of the roads and the vertical position a clear signal for the other. At night a red lantern is suspended from each end of the arm to indicate its position. Another arrangement is the use of two gates—one for each track. Each gate stands normally across its track, and to give the right of way to an approaching train the gate in front of it is swung to clear. Still another arrangement is the use

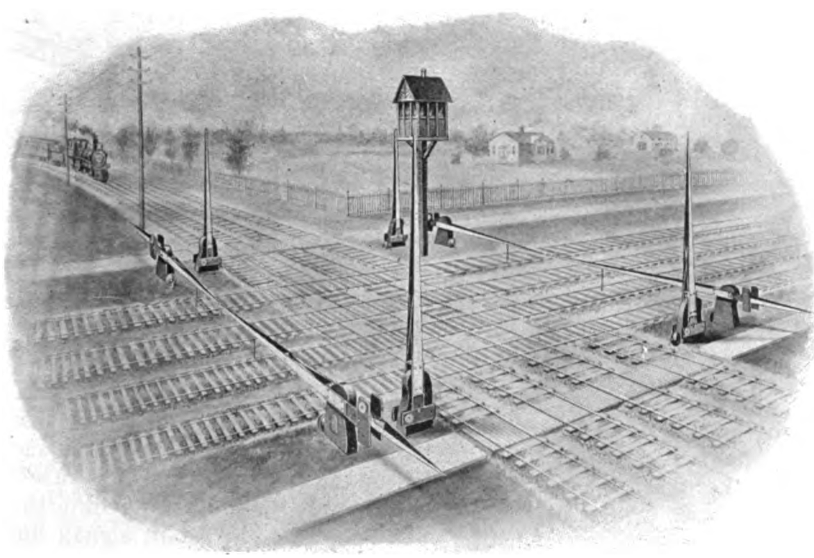


Fig. 233 A.—Double Interlocked Gates at a Track Crossing.

of two sets of gates—one set for each track—interlocked so that one set is always down while the other is up, thus making it impossible to clear both routes at the same time. Such an installation is in service at the crossing of the Illinois Central and the Wabash roads at Decatur, Ill., arranged as shown in Fig. 233A. Similar installations are used to some extent at crossings of steam and street railways.

It is to be remarked that with signals of any kind at the crossing only, the trains must be run under such control that a stop can be made within the limits of vision. The next step in advance is an arrangement of home and distant signals to control the movement of trains on each track, all the signals being so interlocked that only one route over the crossing can be cleared at a time. Normally all the signals on both routes stand at danger, and after a signal on either route is moved to clear, all the signals on the conflicting route or routes are locked at danger and cannot be moved so long as any signal on the first route stands at clear. The placing of signals at a distance in this manner permits high speed over the crossing, but, like the gate, does not always give protection, as engineers sometimes fail to regard the signals and a collision on the crossing sometimes occurs. The only sure means of protection against collision that is in general service is to interlock the signals with derails in each track, one in each direction from the crossing, the derails remaining open while the signals on the same track stand to danger. If the derails are located farther from the crossing than a derailed train can run over the ties a collision at the crossing is a physical impossibility. In the East it is quite commonly the practice to protect crossings with interlocking signals without derails, while in the West the use of derails at interlocked crossings is the rule. Where derails are used at proper distance from the crossing collisions are avoided, but from non-observance of signals derailments occur with more or less frequency, sometimes doing considerable damage. As between the two systems that which makes use of derails seems to be the preferable one and to be increasing in favor.

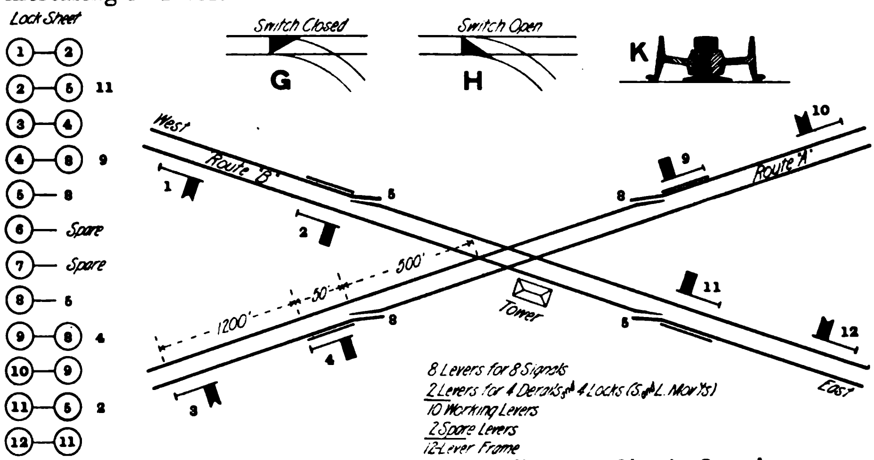


Fig. 234.—Interlocking Signals and Derails for a Simple Crossing.

The Rowell-Potter system of interlocking uses automatic brake-setting devices in lieu of derails. The arrangement consists of a track instrument, known as a "safety stop," that is interlocked with the signal in such a manner that when the signal is at danger the track instrument is raised in position to trip a valve on the engine and apply the brakes. At interlocked crossings this track instrument is placed near each distant signal, and a train approaching the crossing on one of the tracks, while still at a safe distance, causes the distant signals on the conflicting route to be set to danger. Should an engineer disregard one of these signals set to danger the safety stop will automatically apply the brakes and bring his train to a standstill. The device is used with block signals as well as at interlocked crossings. The energy for moving the signals and other parts of the apparatus is derived from a "power-storing" machine that is worked by the undulatory motion of the rails under traffic. The operation and control of the system is thus automatic, no operator or attendant being required. An installation of this system at a crossing of the Peoria, Decatur & Evansville and the St. Louis, Peoria & Northern roads, at Hawley, Ill., was fully described and illustrated in the Railway and Engineering Review of Jan. 6, 1900. An illustrated article on the system applied to block signaling, on the Milwaukee division of the Chicago, Milwaukee & St. Paul Ry., was published in the Railway and Engineering Review of March 15, 1902.

The interlocking tower or cabin is located where a clear view may be had along both tracks. In selecting the location one should seek to avoid the possibility of having to move the tower to make room for laying a second track. Derails are usually located 300 to 500 ft. from the crossing, the distance in some states being regulated by law. With the increasing speed of trains 500 ft. is not too far. Unless the ground on that side is unfavorable, and other conditions do not interfere, derails are placed on the engineer's side of the track. If, however, the tracks cross at a small angle it is in accordance with what is considered best practice to place the derails on the side of the larger angle, as in Fig. 234, with the pipe lines on the opposite side of the track. To hold a derailed train to the ties a guard rail is laid 8 to 12 ins. inside the opposite rail, extending from the derailing point to within a distance of about 100 ft. from the crossing. The home signal is located 50 ft. in advance of the derail, and the distant signal 1200 to 4500 ft. in advance of the home signal, depending upon the grades, but usually 1200 to 2000 ft. for level track. The detector bar for derails extends from the derail toward the home signal, nearly or quite covering the distance between the two. Hence, after an engine passes the home signal at clear the derail cannot be opened. To prevent a derail from being opened while a short train is on a crossing or anywhere between the derails at either side of the crossing, detector bars are sometimes placed on the rails near to and each side of the crossing. Where electric locking is used, as described further along, this precaution is unnecessary.

The ordinary arrangement is to have all the signals and derails stand normally at danger, and upon the approach of a train the derails, switches and signals controlling that route are cleared. The mechanism of an interlocking machine is so arranged that the levers controlling a route must be thrown in a certain sequence, which provides that all the switches and derails of the route must be closed and locked before the home signal can be moved to clear, and the home signal must be cleared in advance of the distant signal. Conversely, no switch or derail on any route can be opened until first the distant and then the home signal has been set to danger; and the closing of a derail or switch on one of the routes locks up all of the derails and signals set to danger on the conflicting route or routes. No switch or signal controlling a route can be cleared until all the switches and signals on the opposing route or routes have been restored to normal —the locking will not permit any lever to be thrown out of its turn. Conventionally, the "normal" position of a lever on an interlocking machine is that in which it stands when pushed from the operator, as in Fig. 219. In pulling a lever to move a signal to clear or to close a derail or switch the lever is said to be "reversed."

A sketch and diagram of the simplest case of interlocking the signals and derails for a crossing of two tracks are shown in Fig. 234. To simplify matters it will be supposed that the derails and detector bars are operated by switch and lock movements. The two derails on each track are thrown by one lever, and the eight signals by one lever each, making ten working levers in the plant. As, however, mechanical interlocking machines are usually built up in sets of eight levers each, with a half set to finish out with in case a full set is not needed, a 12-lever machine is usually provided, so that in the plant under consideration there would be two spare levers. It will be understood that the levers of the machine are numbered to correspond with the derails and signals which they operate. Referring now to the figure, suppose it is desired to "set up" or clear Route "B" for the movement of a train over the crossing from west to east. The first thing to do would be to close the derails by reversing the lever 5. The reversing of this lever locks derail lever 8 in the normal position and releases home signal lever 2. The next movement in order is to reverse lever 2, which locks up derail lever 5 reversed and home signal lever 11 in the normal or danger position, since this signal is used only for west-bound movements; and it is a principle of interlocking not to clear the signals on a track for trains in more than one direction at a time. The latching of lever 2 reversed releases distant signal lever 1. The reversal of distant signal lever 1 completely clears the route for an east-bound train.

The locking is arranged in the most simple manner to effect the purpose, the reversal of each lever locking only such levers as could be thrown to conflict with the route that is being set up. The reversing of a lever does not directly lock every other lever having to do with the control of the route, but only such lever or levers as is necessary to complete the chain of locking—the second lever pulled locks the first, the third the second, and so on. For instance, the locking of derail lever 8 normal by reversing lever 5 accomplishes the locking of all the signals on Route "A," although lever 5 does not directly lock the levers for these signals. To clear the signals on Route "A" it is necessary to first reverse derail lever 8, and hence by locking this lever the signal levers become locked in consequence. Having cleared the signals and closed the derails on Route "B," it is impossible to clear any signal or close any derail on Route "A," and hence by means of interlocking it is impossible for an operator in the tower to give right of way over two conflicting routes at the same time. To assist the operator to quickly pick out the levers of a set, each lever, besides being numbered, is painted in colors to correspond to the kind of service which it performs. The switch levers are usually painted black, home signal levers red, distant signal levers green, lock levers blue; and the levers for switch and lock movements half black and half blue.

It might be said here that the distant signals of mechanical interlocking plants are not always operated by lever and mechanical connections. On the Eastern division of the Pittsburg, Ft. Wayne & Chicago Ry., for example, the distant signals for interlocking plants are operated automatically. They stand normally at caution (that is, 45 deg. from the horizontal, the 3-position signal being the standard block signal on this road) and are cleared through a circuit closer on the home signal when that signal goes to the clear position. They are located a full block (about $\frac{3}{4}$ mile) from the home signals, which is a much greater distance than is feasible for satisfactory operation by means of wire connections.

In sketching the layout of an interlocking plant it is conventional to illustrate the locking performed by each lever in its reversed position by means of a diagram known as a "locking sheet," as shown at the left in Fig. 234. In this diagram the circles enclosing the figures indicating the numbers of the levers are intended to mean that such levers are reversed; where a circle is not used the lever is supposed to stand in the normal or danger position. For illustration, beginning at the top of the diagram, the reversal of lever 1 locks lever 2 in the reversed position; the reversal of lever 2 locks lever 5 reversed and lever 11 normal; the reversal of lever 3 locks lever 4 reversed, and so on. The conventional sign on a drawing for indicating the position of a switch is a triangular spot, as shown in Sketches *G* and *H*, Fig. 234. When the switch is closed or set for main track the vertex nearest the frog is against the through main rail (Sketch *G*), and when the switch is open or set for the turnout this vertex is against the inner turnout rail, as in Sketch *H*.

Plants with 10 active levers for the simplest case of interlocking a crossing of two tracks, working both derails in each track on one lever, with switch and lock movements, are frequently used, but in what is considered best practice the locking of the derails is by means of facing-point locks, each facing-point lock and detector bar being operated together and by a lever separate from that which throws the switch. In this arrangement there is one lever for the two derails and one for the two facing-point locks, in each track, besides eight levers for eight signals, making 12 working levers in the plant. Where detector bars are used at the crossing there is another lever, making 13 working levers, and requiring a 16-lever frame. Where facing-point locks are used it is necessary to reverse a lever locking up the derail before the home signal can be cleared. The home signal lever reversed then locks the lock lever reversed. The interlocking of a crossing on double track can be performed by the same number of levers, numbered in the same manner as those shown in Fig. 234, except that the home signals when reversed do not lock the home signals governing trains running in the opposite direction, as is the case on single track; on double track the two home signals governing trains in opposite directions on the same route are cleared at the same time. On double track it is usual to protect the crossing against reverse movements by means of a "back-up" derail located on each track as far beyond the crossing as the derail for direct movements is in advance of it. The position of these back-up derails is indicated by means of dwarf signals, which are locked in the normal position by reversing the home signal lever, as was explained for movements on single track.

Interlocking Machines.—Of mechanical interlocking machines in use in this country there are two different patterns, known as the Stevens and the Saxby & Farmer. Both of these designs, as now used, are improvements upon the early machines invented and first used in England. With the old form of Stevens machine the locking was accomplished by the initiatory movement of the lever, making it possible to bring a heavy strain upon the interlocking parts in case an attempt was made to throw a lever which had not been released. With the Saxby & Farmer machine the locking takes place preliminary to the movement of the lever, during the operation of unlatching the same, and the releasing is subsequent to the lever movement, while the lever is being latched up at the end of the stroke. This style of locking is known as "latch locking." On the improved Stevens machine latch locking is employed. The improvement of the Saxby & Farmer machine has been the substitution of dog and tappet for dog and "flop" locking and the use of a single tier instead of a double tier of locking bars. The interlocking machine shown in Fig. 219 is of the Saxby & Farmer design, as made by the Union Switch & Signal Co. The levers are spaced 5 ins. apart, and, lacking those omitted in the "spare" spaces, there are 92 of them in view. The levers are all pivoted to a long frame running lengthwise the building underneath the floor. But little more than half the lever appears in the view. The levers are L-shaped, being bent out at a right angle at the lower end and pivoted at the bend, with the vertical switch, signal or lock connection attached to the end of the arm. For the double wires of signals an extra arm, called a "tail piece," is bolted to the lever on the side opposite the bent arm, for attaching the back-pull wire. The lever is latched into a quadrant, like the reverse lever of a locomotive.

The locking of the levers is effected by two sets of bars at right angles to each other, working in combination, each bar of one of these sets being attached to and actuated by the lever latch. Starting with the lever, the latch rod carries a sliding block which works in the slot of a rocker centrally pivoted to the side of the quadrant into which the lever is latched. This slotted rocker or "rocker link" appears at the front of each lever, in Fig. 219, and by means of a link and crank its back end is connected to a horizontal "locking shaft" extending under and at right angles to the "locking board." This locking board is the horizontally arranged system of parallel bars appearing back of the levers, and consists of "locking bars," running lengthwise the machine or building, and other bars known as "cross-locks" which are seen lying across the locking bars at intervals. Each locking bar is driven longitudinally by a locking shaft, which, as above explained, is in connection with the latch of one of the levers through a crank, link and slotted rocker. The cross locks consist of notched bars

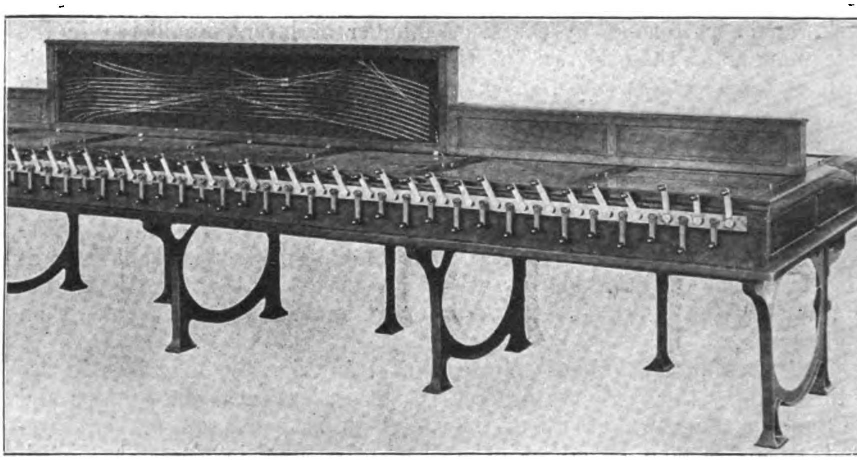


Fig. 235—Electro-Pneumatic Interlocking Machine (Front View).

or tappets, each of which is notched once for each lever to be locked. The motion of the cross locks is imparted by means of bevel-ended lugs, called "dogs," riveted to the locking bars, which engage with the bevel-shaped notches of the cross locks. When the operator starts to reverse a lever he pulls upon the latch handle, and, if the lever is not locked, the back end of the rocker is lifted, throwing a locking bar and locking such levers of the conflicting routes as are not already locked by some other lever. This locking is accomplished by the movement of the dogs on the locking bar into the notches of all cross locks which could be moved by the levers thus locked. In reversing the lever the rocker remains stationary, the radius of the slot in the same being equal to the distance from the sliding block on the latch rod to the pivot of the lever, the latch rod meanwhile being stopped against dropping down by the top of the quadrant. When the lever is thrown to the reverse position the latch spring forces the latch bar into its notch at the end of the quadrant, which acts to depress the end of the slotted rocker, throwing up the opposite end and imparting further longitudinal motion to the locking bar, which releases the lever to be thrown next in sequence.

On the Stevens machines made by the National Switch & Signal Co., some years ago and extensively put into service, the arrangement of the latch and rocker is the same as in the Saxby & Farmer machine just described, except that the rocker is lower than the top of the quadrant, being under the floor. The locking board is also under the floor, being arranged vertically on the frame of the machine. In the locking of this machine the rocker of each lever is attached to a tappet bar working vertically on the locking board, and the locking is by means of dogs attached to narrow bars working horizontally. Each dog is made longer than the distance between two tappet bars by the depth of a triangular notch cut in the tappet bar which it locks. The end of the dog is shaped to fit this notch, and when it slides into the same it leaves the other tappet bar free to move. In order to release one lever and lock up another—call them, for the purpose of illustration, levers 1 and 2, respectively—the notch in the tappet of lever 2 must be opposite the notch in the tappet of lever 1, which is engaged by the dog. Then by throwing lever 1 the beveled face of the tappet notch will force the dog over into the notch of the tappet of lever 2, locking lever 2 and releasing lever 1. On general principles the locking of the two patterns of machines is the same, the locking bars and dogs in the one case actuating the tappets (cross locks) and in the other case (National machine) the tappets actuating the dogs, which are attached to what would correspond to the locking bars of the Union machine. The arrangement of the Johnson machine is quite similar to that of the National, the only material difference being in the location of the rocker, which is pivoted to a bracket fastened to and moving with the lever instead of being attached to the frame of the machine, as is the case with the National.

The locking of the levers of the different power machines is by means of a mechanical locking board or "locking bed" arranged on the dog and tappet principle, as already described. Stated in a general way, the signals in each of the several power systems are operated by mechanisms of the same class as those which operate the switches. The interlocking machine of the electro-pneumatic system (Fig. 235) differs from a mechanical machine in having a crank and shaft in place of the upright lever and rocker. These cranks constitute the "levers" of the machine, those in the upper row usually operating the switches and those in the lower row the signals; although in some instances the two classes of levers are grouped, and intermixed between the two rows. The shafts turned by the cranks extend under and engage with the locking bars, as on a mechanical machine. The connection between each shaft and its locking bar is by means of a segmental pinion on the shaft and a rack cut in the bar. The locking is by locking bars, dogs and cross locks, as with a mechanical machine. In operating a "lever" the shaft across the machine is rotated about 60 deg., making electrical contacts at the rear end which close the circuit controlling the valves of the switch or signal cylinder. Figure 235 is a front view of part of a machine of this type, showing the operating levers and a miniature model of the tracks controlled. This model is formed of light brass strips, and the switches on the same, being in mechanical connection with the levers, on the back side of the vertical board, move in harmony with the switches on the roadbed, thus representing at all times the actual track connections. The working parts of the machine are enclosed in a wooden case with a glass top. A rear view of the machine with the casing removed, showing the half-size Saxby & Farmer improved interlocking and the electrical switches and indication attachments at the rear of the locking shafts, is presented as Fig. 236. Each switch consists of a section of hard rubber tube mounted upon a locking shaft, to insulate small brass bands which extend partly around the tubing and form contacts with springs bearing against the tubing. As the shaft is turned the brass strips connect the pairs of springs, closing the circuits in succession, and in the order in which the bands are arranged on the roller. As the electro-pneumatic system uses current at all times, whether movements are being made or not, the electrical supply is usually furnished by a small dynamo operated in connection with the air compressor plant, with storage batteries to maintain operation while the dynamo is not running. The electromotive force of the switch and signal circuits is usually 12 to 16 volts.

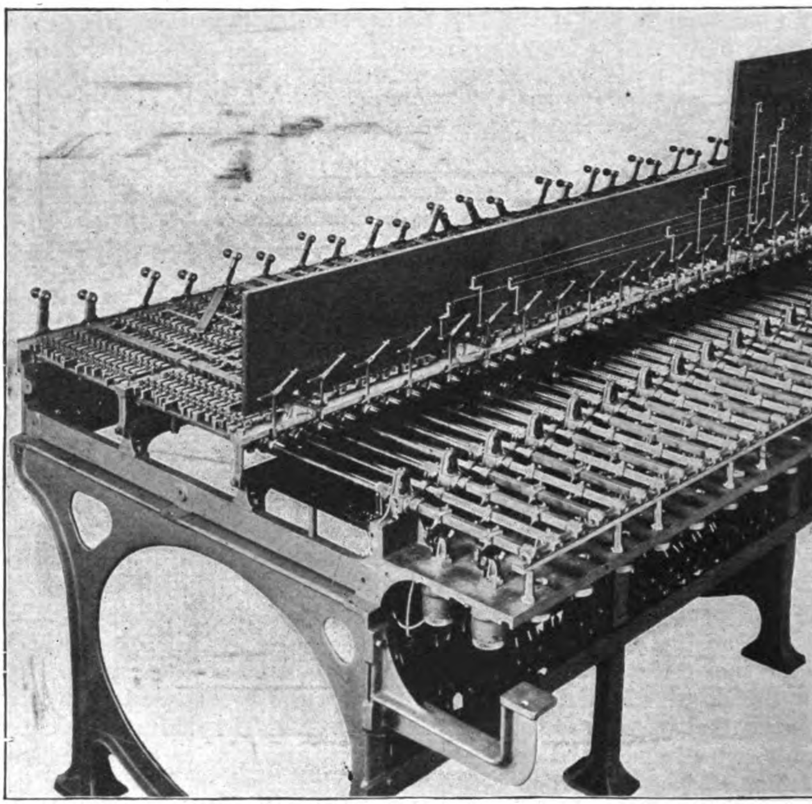


Fig. 236.—Electro-Pneumatic Interlocking Machine (Rear View, Cover Removed).

Each signal is operated by a cylinder of 3 ins. diam. and 4 ins. stroke, the valves admitting air to and exhausting it from the same being controlled by an electro-magnet. As the signal or semaphore arm is counterweighted to rest by gravity in the danger position the cylinder is single-acting only. Air is admitted to move the signal to safety, and when it is exhausted the counterweight or overbalance of the back casting brings the blade back to danger. To prevent the lever from being returned to normal in case the signal should fail to go to danger after the air is exhausted from the cylinder there is an electro-magnetic lock which engages the lever, upon making a partial stroke with the same toward normal. This lock is under the control of a circuit which makes contact with the signal movement. The failure of a signal to return to danger thus prevents the return of the operating lever to normal, and until this can be done the switches remain locked to safety and cannot be moved. The signal cylinder is sometimes placed high up on the pole and sometimes it is located under cover at the foot of a hollow iron pole, operating the signal by means of a rod passing up on the interior of the pole.

In the Standard or low-pressure pneumatic system of interlocking, the signal cylinders, which are attached to the poles, high above the ground (Fig. 226) are worked by valves and operating pipes of the same general style as those for the switches. The locking of the levers (Fig. 237) is by dog and tappet arranged on a vertical board similar to that in service in ordinary mechanical interlocking. At the switch there is a valve which controls the flow of air to the signal cylinder in such manner that the signal cannot be cleared until the switch is in its proper position. The mechanism for operating the signals is arranged to give an indication for only the normal or danger position of the signal. This indication is given in the same manner as the switch indication. It is considered unnecessary to require an indication for the signal in its clear or safety position.

In the Thomas pneumatic interlocking system the semaphore is brought to the normal or danger position by a counterweight. The control of the valve admitting pressure to or exhausting it from the working cylinder of the signal is by means of a piston of the equalizing type actuated by a sudden increase or decrease of pressure, as explained in connection with the operation of the switch cylinder. With the signal mechanism, however, there is only one controlling pipe. Normally the pressure in this pipe is 70 lbs. per sq. in., and to put the signal to safety it must be increased. As in the operation of the switch cylinder, this is done by manipulating a valve on the interlocking machine (Fig. 229) and admitting air at 80 lbs. pressure. To restore the signal to the normal position the valve is moved to establish communication between the controlling pipe and an empty reservoir, reducing the pressure again to 70 lbs., causing the controlling valve at the signal cylinder to shift and exhaust the air from behind the working piston, thus permitting the counterweight to take the signal to danger. When the signal is in its normal position the indication pipe contains air at maximum pressure, the indicating mechanism being

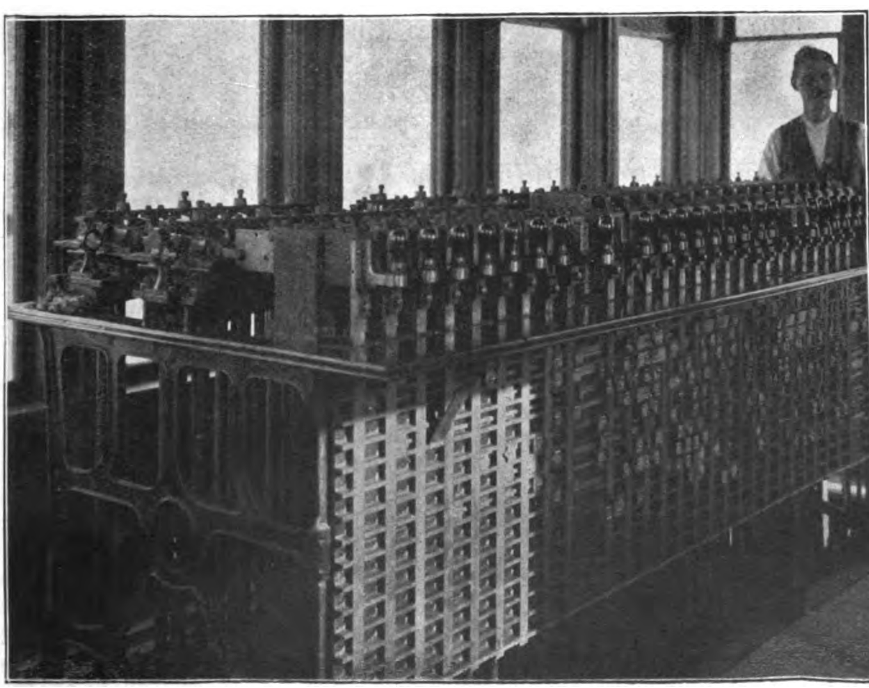


Fig. 237.—"Standard" Pneumatic Interlocking Machine.

so arranged that an increase of pressure must take place in the indication pipe before the lever operating the signal can be thrown full stroke or near enough to its normal position to release conflicting levers. When the signal is moved to clear, it actuates the indication valve, reducing the pressure in the indication pipe to 70 lbs. and permitting the lever to be thrown full stroke. Should the signal fail to respond properly to the lever movement this reduction of pressure would not take place, the lever could not be moved its full stroke, and hence all conflicting levers would remain locked. The time required for operating a signal 300 ft. away is about one second; at a distance of 1000 ft. it is three seconds, and at a distance of 2000 ft. 5½ seconds. It is not necessary to wait for pressure to equalize. By actual test a signal was handled 20 times per minute at a distance of 1000 ft. The levers of the Thomas machine are mechanically interlocked on the cross-locking principle.

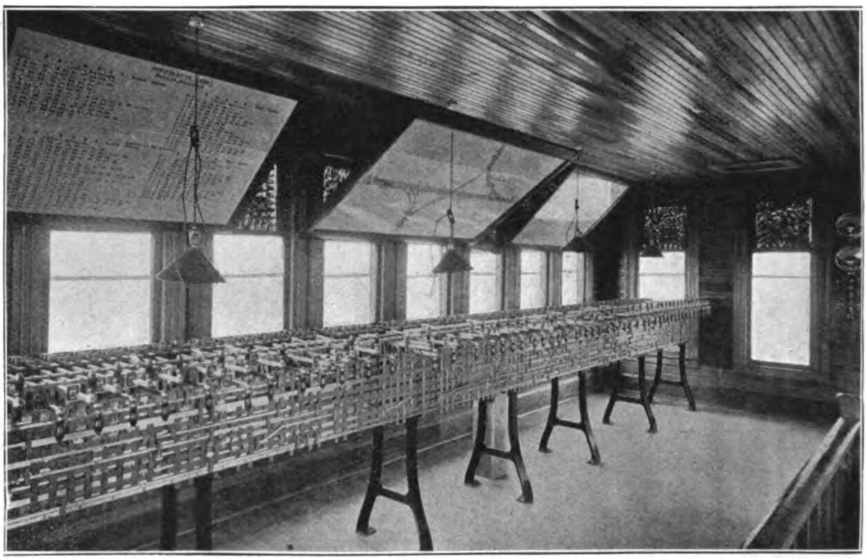


Fig. 238.—Taylor Electric Interlocking Machine (Casing Removed).

The "levers" of the interlocking machine of the Taylor electric system (Fig. 238) are straight steel bars with handles at right angles, pushed from the operator for the normal position and pulling straight out to the front when reversed. Each lever is connected with a circuit closer on the switch or signal circuit, as the case may be, and the levers are interlocked in the ordinary mechanical manner. The signal machine is worked by a motor of one-sixth horse power placed on a bracket fastened to the side of the pole some distance from the ground. To bring the signal from the normal or danger to the clear position the motor turns a sheave which winds up a chain and lifts the weighted end of the balance lever, pushing up the signal rod and throwing the semaphore arm down. As soon as the signal reaches the clear position a pole changer is operated, as in the action of the switch machine, closing the circuit through a brake magnet which holds the signal in this position and opens the main circuit to the motor. The pressure generated by the motor sends a current for the back indication to the interlocking machine and checks the momentum of the armature, the same as with the switch machine. To return the signal to normal the electro-magnetic brake is de-energized and the counterweight pulls the blade to the horizontal position. As the blade swings up to this position it operates a circuit closer which returns an indication to the tower. The indication current operates an electromagnet which works a releasing latch on the lever, permitting the stroke of the same to be completed. As with all other power machines, the first movement of the operating lever, either from the normal or the reverse position, is only partial stroke. Without the indication the full stroke of the lever and the release of conflicting levers interlocked with the same cannot take place.

Attention should be called to the practice of lighting signal lamps by electricity in connection with the Taylor system of electric interlocking. The generators and storage batteries used with this system afford special facilities for lights of this kind. Incandescent lamps of 4 candle power are generally used, and besides the signal lamps the lamps on switches in near-by yards, thrown by hand stands, are sometimes lighted from the same source. The dynamo for charging the storage batteries for a plant of this kind is usually located in the first story of the tower, or in a small building outside, and is driven by a gasoline engine attended to by the tower man, it being necessary to keep the charging plant running only a small portion of the time. Batteries in sets of 55 cells each, supplying current at 110 volts, is a common arrangement. It is also customary to arrange the connections of the dynamo circuit so that the interlocking machine may take its supply of electricity direct from the generating plant instead of from the storage battery. By this arrangement there is provision for maintaining the plant in operation in case it should become necessary to temporarily cut the battery out of circuit for repairs. In large plants it is usually arranged to have two sets of generators and batteries, each of which has a capacity sufficient for operating the plant.

The machine shown in Fig. 238 has a 136-lever frame and is 22 ft. long. It has 51 levers for operating switches and derails, 55 signal levers and one lock lever, the switch levers being disposed in the upper row and the signal levers in the lower row. There are two sets of storage batteries of 55 cells each, having a capacity of 150 ampere-hours each. There are duplicate generating sets, each consisting of a 2-k. w. dynamo and a 5-h.p. gasoline engine. In lieu of detector bars at the crossing of the tracks controlled from this plant track circuits 400 ft. in length are used; that is, they extend 200 ft. each side the crossing in each track, or nearly to the derail. This arrangement prevents the opening of a derail when an engine or short train is anywhere between the derails on either side of the crossing, and gives better protection than the ordinary arrangement of crossing bars with mechanical plants, where a detector bar 40 to 50 ft. in length is used on either side of the crossing to prevent opening a derail when an engine or short train is standing upon or moving over the crossing. The conducting wires of the switch and signal circuits are carried in wooden trunking, supported just above the surface of the ground on stakes set about 8 ft. apart.

Auxiliaries.—A safety device known as "electric locking" is frequently applied to an interlocking system to prevent the derail of a route being opened in front of a train after it has passed the distant signal set to clear. Unless some protection of this kind is afforded derailments may sometimes occur, for instances have been numerous where the operator took the home signal from a train and opened the derail when the train was so near that a stop could not be made before being derailed. The explanation of such performances is that an operator will sometimes forget, momentarily, that a train has entered the interlocking region, and out of confusion or while in a sleepy condition may take the signals from this train and give them to a train on a conflicting route. Electric locking is also a check upon an engineer who goes off at the derail and claims that the operator "took the rail" from him after passing the distant signal at clear. The mechanism of electric locking consists of electro-magnets arranged on the locking board in position to engage with the locking bars of the derail or switch levers or the lock levers. Normally the armature bars of these magnets are held up, but when a distant signal is cleared the circuit through the lock is broken, de-energizing the magnet and dropping the armature, which engages with a lug on the locking bar and thus locks up the derail lever. To prevent the operator from getting at these locks to lift an armature, prematurely, each of them is enclosed in a heavy case the cover of which is secured by a padlock. In this manner the control of a route is taken out of the hands of the signal operator after the signals have been cleared for an approaching train, and cannot be recovered until the train has passed over the crossing or out of the interlocking.

The circuits controlling these magnets are arranged in various ways. Sometimes circuit breakers are attached to the signal levers, so as to open the circuit when the lever is reversed, and sometimes the circuit breaker is operated by the blade of the distant signal. In interlocking practice the distant signal is returned to the normal or caution position as soon as it is passed by the train for which it is cleared, and the usual arrangement to prevent the locking circuit from being restored when this is done is a track circuit between the distant and home signals. When a train is on this circuit the armature of the relay breaks the circuit through the locks. As soon as the train passes the crossing or the derail beyond the same a track circuit arrangement restores the lock circuit, lifting the latches and releasing the derail levers. Others arrangements are described in papers read before the Railway Signaling Club: one by Mr. W. H. Elliott, Nov. 12, 1895, and another by Mr. V. K. Spicer, May 12, 1896 (The first-named paper was published in the Railway Review for Dec. 7, 1895, and the last-named in the issue for May 16, 1896. A discussion of Mr. Spicer's paper was published in the issue for July 25, 1896.)

To provide for unlocking the machine in case a train should stop within the interlocking limits, or the track circuit become short-circuited, or after trying the levers during bad weather to see if the system is in working order; or, in event of delay to the train for which the route is set, to give right of way over the crossing to a train on another route, a releasing circuit with a switch in a box under a glass cover is sometimes arranged. In order to close the circuit to release the locks it is necessary to break the glass, so as to get at the switch, thus leaving a record of the instance of irregular working, the occasion for which the operator is supposed to explain. Numerous other devices have been used for the same purpose, such as a slow-motion hand releasing screw at an inconvenient point, a releasing button located down stairs or at some distance from the operating room, etc., the idea being to interfere with hasty action and cause the towerman to think of what he is doing, in case his intention is suddenly decided upon, as when awakening from sleep, etc. The tendency with all these special releasing devices has been a too frequent use of the same, with resulting carelessness and disregard of the purpose of electric locking, operators in many instances going so far as to rig up secret circuits, jump wires etc., in order to work the release without special effort.

Time Locks.—The difficulties with the working of electric locks under certain conditions have to some extent led to the use of time locks. The purpose of the time lock is to prevent, for a desired interval of time, the opening of the derail after the home signal has been set to danger. One style of time lock consists of a vertical rack bar placed in engagement with some gear wheels under the control of an escapement. This rack bar is attached to the home signal lever, and controls a lock on the derail lever in such a manner that the derail lever cannot be moved from its reversed position except while the rack bar is down. In reversing the home signal lever, or when setting it to clear, this rack bar is raised, and is not released from the raised position until the home signal lever is set to danger. Upon being released the bar drops by gravity, the gradual descent being timed by the escapement mechanism, which can be set to work to any desired interval of time. At the end of this interval the rack bar reaches its normal position, releasing the derail lever. In some instances this interval corresponds to the time required for a fast train to pass from the distant signal to and over the crossing, and in other instances it is made to correspond to a similar transit of a train running at an average speed or at slow speed. Another style of time lock is operated pneumatically. It consists of a cylinder and piston with a quick-acting valve operating for the motion of the piston in one direction and a small leak hole which permits atmospheric pressure to gradually return the piston to normal position after being forced up by the home signal lever, thereby forming a partial vacuum at one end of the cylinder. The return of the piston releases the lock lever or derail lever. Still another time-lock mechanism which is attached to the levers and locking in the same manner, and operating quite similarly, is a hydraulic device in which a liquid is used instead of air to oppose the quick return of the plunger rod after being released by throwing the home signal lever to normal.

One situation where electric locking or time locks could be particularly serviceable, and where one or the other ought to be applied, is at the end of double track. Bad collision wrecks have happened at the end of double track through the confusion of switch tenders, who, being suddenly seized with an impression that the switch was set wrong, have been known to throw the switch for the second track immediately in front of a fast passenger train, resulting in collision with a train standing on second track. A safe way to operate such switches would be to have a distant signal on the single track interlocked with the switch stand, and then have the stand controlled by a track circuit and electric lock or by a time lock.

Bolt Locks.—Another safety device is an arrangement to prevent the clearing of the home signal in case the switch or derail should fail to close properly or fail to move at all, as might happen if the connection should break. It is known as a bolt lock, the usual form of which consists of two flat bars sliding edgewise in guides at right angles to each other, one bar being connected to the switch and the other to the signal wire or pipe line; each being so notched that when the switch is closed and the signal at danger either bar is free to move, but the movement of one locks the other. The arrangement is shown in Fig. 222 in connection with a switch and lock movement, the switch bar of the bolt lock being an extension of the lock rod. In the position shown the signal is locked to danger. Should the switch now be thrown and the point rail not move properly up to its place the notch in the switch connection will not come in line with the bar on the signal connection and the signal cannot be moved. The notch in the signal connection is long enough to allow some latitude of adjustment due to expansion or contraction of the wire, stretch, etc., but will not permit any considerable movement of the signal wire. The connection to the switch being short and rigid, the width of the notch in that is made to correspond to the thickness of the bar on the signal connection. When the switch is properly closed and the signal set to clear, the bolt lock then locks the switch, the latter then being locked by two devices—the switch and lock movement and the bolt lock. Should a facing-point lock be used and the switch connection break, the switch lever might be thrown without moving the switch, in which case the lock plunger would enter the same hole and lock the switch in the wrong position, releasing the signal lever, so that the signal could be cleared without closing the switch. With the bolt lock such a misplacement cannot occur, for, as above explained, when the switch is open the bolt lock locks the signal to danger independently of the interlocking of the levers on the machine.

To prevent a disconnected switch from being locked in the wrong position the Michigan Central R. R. uses coiled springs acting against lugs on the head rod, to throw the switch away from the stock rail as soon as the lock plunger is withdrawn, thus preventing the plunger from again entering the lock rod. On this road bolt locks are used on distant as well as home signals, where there are facing-point switches and derails without facing-point locks. This practice is to guard against clearing the distant signal in case the wire which pulls the home signal should break between the bolt lock and the lever. A form of bolt lock differing from that above described consists of a lock rod on the switch connection and a plunger on the signal connection.

Selectors.—Another contrivance that has been much used in interlocking, and which deserves mention in any general treatment of that subject, is the selector. This is a device for operating two or more signals, one at a time, by the same lever, the mechanism being so arranged as to automatically connect the particular signal which governs the route for which a switch has been set. The collection of signals that can be worked by a selector must be such that but one of them need ever be cleared at the same time; as, for instance, the signals governing a succession of branch routes leading from a single track. The purpose of the device is, of course, to reduce the number of levers on the interlocking machine. Selectors are made in several patterns, but the principle involved in the design of all of them is to terminate the connections from the several signals and the connection from the signal lever in one place, to which connections are run from the switches. The arrangement is then such that the setting of the switch for any one of the routes brings the connection from the signal lever into engagement with the connection to the signal governing that route. A common form of mechanism for wire-connected signals is a "hook gear," each signal being connected to a hook-ended bar working between guides on the selector frame, the hook being pulled by a shifting bar or slotted plate connected to the signal lever in the tower, according as the setting of the switch on that route puts the two parts (the hook bar and the lever connection) into engagement. One arrangement for selecting the hook for the proper signal is a driving bar operated by the pipe line to the switch, this driving bar carrying lugs set to throw every hook bar out of engagement except the one to be operated. Another arrangement is a shaft with cam lugs, which, when turned by the switch connection, throw all but the proper hook out of adjustment. A common form of selector for pipe-connected signals consists of slide bars connected to the signals and working in guides on the selector casting, with a shifting slide bar connected to the signal lever. By means of a cross bar in connection with the switch the shifting bar is moved into position to abut against the slide bar of the signal governing that route, and when the signal lever is thrown it pushes the signal to clear, instead of pulling it, as in the case with the selector for wire connections. Such a selector is adapted to be used directly opposite the switch involved in the combination, and the cross bar is usually connected directly to the lock rod of the switch, in which case the selector is made to act also as a bolt lock.

Selectors are known as one-way, two-way, three-way, etc., according to the number of switches connected with it and not by the number of selector rods or signals. It is not usual to make selectors larger than eight-way, and in general practice the size or capacity is seldom as large as that, the preference being with selectors for not more than two signals. The general tendency, however, is to abolish the use of selectors, as with switches less than about 700 ft. from the tower the cost of the selector is as much as that of an extra lever and line of pipe.

To conclude, it may be stated that as far as may be feasible, grade crossings should not be so located that trains on either track, in the vicinity of the crossing, will have to approach it on a considerable down grade. Wherever a difficulty arises in this respect, it is better, if the expense be not too great, to avoid crossing at grade altogether; but if not, then an interlocking plant with derailing switches should by all means be installed for the crossing.

Subways for Interlocking Pipes and Wires.—To carry a large number of interlocking pipes under a track and maintain satisfactory support for the track requires special construction, particularly in the case of lead-out connections at the tower, where the pipes are close together and a large number of them cannot easily be spread apart to dodge the ties. As such pipes are usually spaced 2½ or 3 ins. centers, any support for the track must be arranged to occupy as little space as may be practicable between the pipes. It is evident that if the track support consists of wooden ties the space between each two ties permits of room for only a few pipes, so that in case a large number of pipes are to be laid they must be arranged in groups corresponding to the tie spacings. In case the general course of the pipe line runs diagonal to the track at such an angle that the ties cannot be conveniently skewed to conform thereto, the pipe line is broken by bell cranks and extended squarely across the track. To get room for interlocking connections it is quite customary to lay the ties widely spaced, and to support the rail over these wide spacings in case of breakage it is sometimes the practice to lay a rail on side on either side of each running rail, as in Sketch *K*, Fig. 234.

There are two ways of reducing the space occupied by the immediate supports for the rail without reducing the bearing area on the ballast. One arrangement, illustrated as Plan *A*, Fig. 239, is to use large ties and depress them far enough to carry the rails on small pieces which afford more space for the pipe lines. In order to obtain room for tamping, the rail is supported on 4x5-in. oak strips spiked to the tops of 8x10-in. ties on flat, Servis tie plates being used on the 4x5-in. strips. This arrangement affords good support for the rail and the pipe lines are separated widely enough in the middle of the spacing to permit the tamping bar to be used. Another and more expensive arrangement is to use heavy or closely spaced under supports, with I-beams to take the bearing of the rail. As the thickness of the I-beam web is less than the clear spacing between the pipes, practically all of the space is available for the cross connections. One arrangement of this kind is shown as Plan *B*, Fig. 239, and another as Fig. 240. In the latter case an 8x10-in. oak sleeper is placed longitudinally under each rail, clearing the rail base by 8⅛ ins. The immediate supports for the rails consist of steel ties, three in number, placed across the sleepers and spaced 16 ins. centers. Two 8x10-in. ties serve as bulkheads. The bed sleepers are held rigidly together by 1-in. iron rods. The pipes are led across the track diagonally through the four

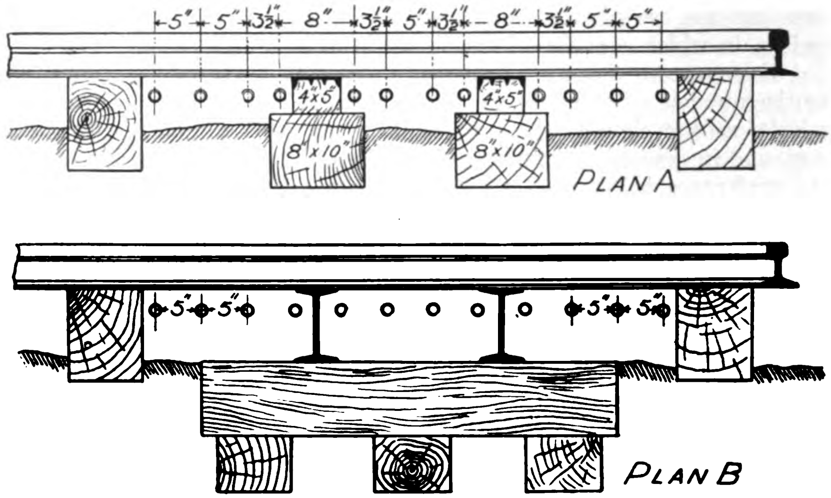


Fig. 239.—Cross Connections for Interlocking, C., M. & St. P. Ry.

openings between the two bulkheads. The rails are secured to the steel ties by clips and $\frac{7}{8}$-in. bolts. The steel tie consists of an I-beam built of an 8x$\frac{1}{2}$-in. web plate, with two 3x4x$\frac{1}{2}$-in. angles for the top flange and two 3x4x$\frac{3}{8}$-in. angles for the bottom flange. The top flange is cut away on one side of the tie, except underneath the rail base, where it is needed as a means of securing the rail clip. Thus practically all of the 64 inches of space between the bulkheads is available for pipes, since the web thickness of the tie support is less than the distance between the pipes.

Where the pipe lines cross the track at a small angle the plan of skewing the ties becomes impracticable, and a subway under the ties, as they lie squarely with the rails, affords the most substantial construction. Figure 241 shows the plan of such a subway for 25 lines of pipe and 10 signal wires. A course of 8x16-in. timbers 10 ft. long, spaced 8 ins. in the clear, was first laid to form a platform, to which were spiked four 8-in. I-beams, each 45 ft. long, spaced 2 ft. 6 ins. centers, forming three passageways for the pipe lines and signal wires. The platform timbers, which are laid on a bed of gravel, are indicated in the engraving as grained wood. In order to vary slightly the angle of the subway, so as to permit I-beams of the same length (45 ft.) to be used throughout, the

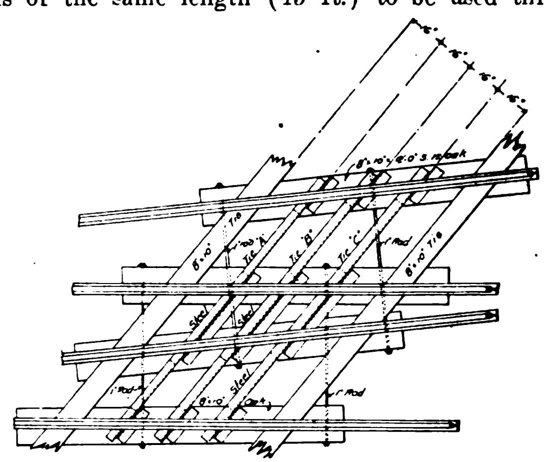


Fig. 240.—Interlocking Cross Connection.

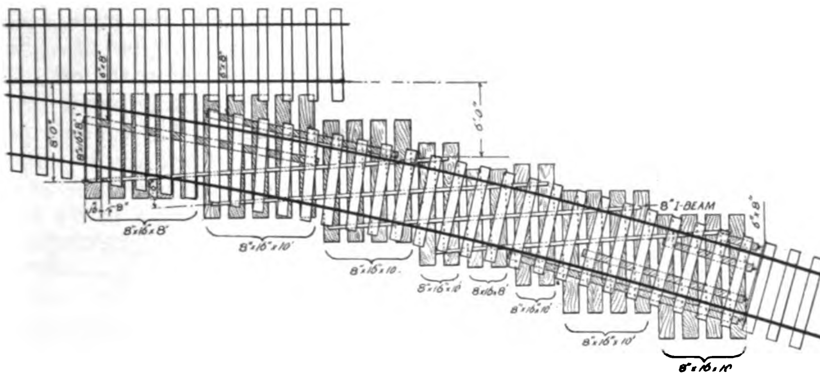


Fig. 241.—Plan of Subway for Interlocking Pipe Lines, C., M. & St. P. Ry.

pipe lines are slightly curved at this point, and the subway does not extend exactly parallel with the main track, as appears from the dimensions in the figure. The track ties supporting the rails are placed squarely across the track and laid upon the I-beams, being supported by 6x8-in. stringers laid upon the platform timbers, where the ties do not get a full bearing upon the I-beams. The general appearance of the subway is shown in Fig. 242, the photograph being taken before the pipes leading through it were boxed over, according to the usual custom, to prevent interference from snow.

The plan of using bell cranks and crossing the track with sections of pipe between the ties usually requires a change in the direction of the lead, with some lost motion in the cranks and their connections; extra length of pipe by reason of the indirect route, and extra resistance from the operation of the bell cranks, and also sometimes from the curve in the lead which is needed to resume the general direction. The construction of a subway of I-beams and timbers requires a good deal of excavation and is expensive. On the Lake Shore & Michigan Southern Ry. use is made of pipe conduits at certain points where interlocking pipes pass under the track. They are easily laid and can be run direct. The use of this style

Fig. 242.—Subway for Interlocking Pipe Lines, C., M. & St. P. Ry.

of underpass is applicable in all situations, but the convenience is especially noticeable where the crossing of the leads is diagonal to the track. Each line of interlocking pipe is carried in a 2-in. conduit pipe filled with crude kerosene oil, with stuffing boxes at the ends to retain the oil. The section of interlocking pipe which works through the stuffing box is turned in a lathe to a smooth surface $1^9/_{32}$ ins. in diameter. The conduit pipes are laid about 12 ins. beneath the ties, and the couplings are of just the right diameter to permit the pipes to be laid to the regular pipe carrier spacing, thus avoiding any difficulty in transition from one to the other.

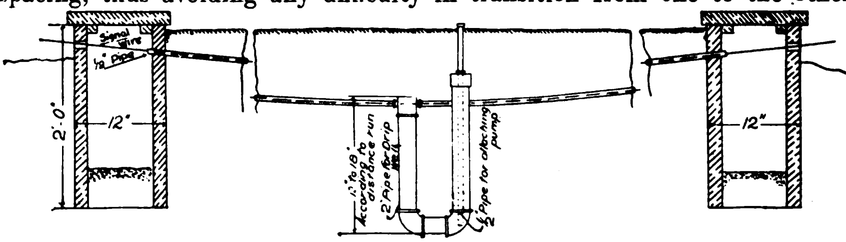


Fig. 243.—Conduit for Signal Wires Under Streets, L. S. & M. S. Ry.

Figure 243B is a photographic view of one of these pipe conduits, the picture at the left showing the stuffing boxes and the capped tubes through which the pipes are filled with oil.

In carrying signal wires under a track they are usually put through the spaces between the ties and left uncovered. As such wires extend considerable distances from the tower they must frequently be carried under public highways or city streets, and at such places a substantial pipe culvert or other subway is desirable. A conduit arranged for the purpose and designed to protect the wires from corrosion is illustrated as Fig. 243. There is a box at either side of the street about 12 ins. square and 2 ft. deep, into which is led one end of a half-inch pipe carrying the signal wire. This pipe sags, and is lowest in the middle of the street, at which point it is joined to a drip well consisting of a piece of 2-in. pipe bent U-shape. Extending upward from the bottom of the "U" there is a short piece of half-inch pipe, capped and made accessible from the street. After the signal wire has been led through its protecting pipe all the pipe is filled with oil from the connection in the street, the oil being permitted to flow to the ends of the pipe in the boxes. During wet weather water follows the signal wire into the protecting pipe and, being heavier than oil, finally seeks the bottom of the U-tube. From time to time the half-inch pipe in the street is opened and a pump is attached and worked until oil

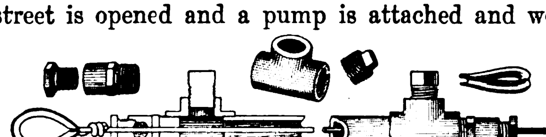


Fig. 243 A.—Wrigley Signal Wire Conduit, Erie R. R.

appears, which indicates that all the water has been removed. The Wrigley conduit for signal wire protection (Fig. 243A), used on the Erie R. R., consists of a line of pipe with stuffing boxes at the ends and T-connections with removable plugs for filling the pipe with crude oil.

84. Switch Protection.—It occasionally happens that a switch is used and carelessly left open to main track, and, if there be no warning, great danger awaits high-speed trains or heavy freight trains approaching in the facing direction. On the whole, railroad companies have been slow to adopt means of protection against such occurrences or the dangers incident thereto. One of the first roads to put into service a contrivance for preventing a switch from being left open to main line after the departure of the train that used it, was the New York, New Haven & Hartford R. R. The arrangement in this instance is a small round house built over the switch stand at facing-point switches, and so devised that a person opening the switch cannot emerge from the house without first throwing the switch to main track and locking it in that position. The doors of these "switch houses" are pivoted to a center post, to revolve like a turnstile, and are painted one side red and the other side white. As one passes into the house the door is reversed and the red side is turned outward. A flat rod in connection with the switch points passes through a slotted casting under the door, and the attachments are such that until the door is reversed the switch is held by this lock rod and cannot be thrown. The opening of the switch then locks the door, and the only way to get out is by closing the switch and locking it, as stated. The house is not provided with glass windows, but on the track side there is a hole through which the man inside may put his head and watch the train movements. While these switch houses have been in satisfactory service on several divisions of the western district of the road since about the year 1882, the scheme has not been adopted to any great extent elsewhere, probably because the use of the same ties up one of the train crew for the time being.

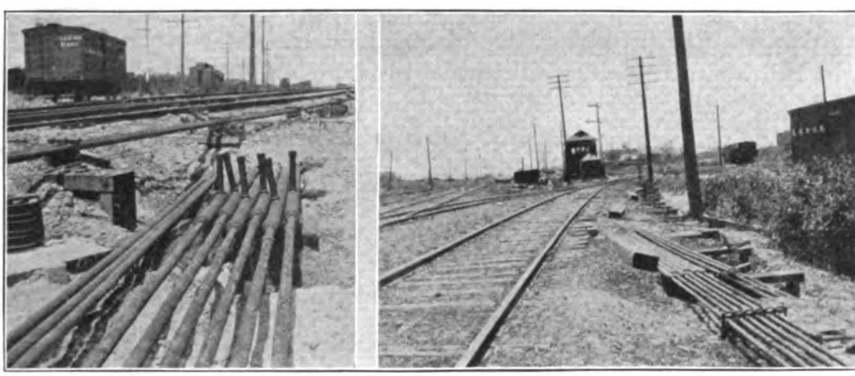


Fig. 243B—Pipe Conduits for Interlocking Pipe Lines, L. S. & M. S. Ry.

The means of protection most widely adopted is a signal displayed at a distance which indicates the position of the switch. It has been well demonstrated that, in the absence of other means of protection, the safety of high-speed trains at facing-point switches requires that advance warning be given of the position of the switch, and particularly at outlying switches where the switch stand or switch light cannot be seen at a good distance away. It has heretofore been pointed out that the high target affords some protection on straight line which is not obtained with the target on switch stands of ordinary hight. On curves, however, any signal at the switch cannot usually give a desirable measure of protection. For this reason it is found necessary to place a signal or signals at points distant from the switch, the same being operated either by the movement of the switch or in connection therewith. The signal most extensively employed at distant points is the semaphore arm operated on a high pole, and experience has shown that the best practice is to operate switch and signal by separate levers. As it is obviously important that the lever operating the switch should not be thrown independently of the lever operating the signal, it is usually arranged to have these levers interlocked in such manner that the switch lever cannot be thrown until the signal lever has placed the signal to danger. This is the essential feature in all modern switch signaling at a distance, the main point of difference in the various devices being in the form and operation of the levers and the method of locking the switch points.

Perhaps the simplest device for interlocking the movement of a switch with a distant signal is a double-lever ground stand, with the signal lever bent to extend across the switch lever, as shown in Fig. 244. In locking the switch the lock then secures both levers. It is plain, however, that this arrangement does not insure that the points have been thrown entirely home, before the signal is cleared, neither does it necessarily hold the switch lever in position for main track until the signal lever has been thrown entirely over to the position placing the signal at danger; that is to say, the switch movement may begin as soon as the signal lever is lifted. A simple device used with facing-point switches on the Chicago & Northwestern Ry. is a horizontal shaft carrying two lugs which are revolved into position straddle the point and stock rails for the closed position of the switch, as in Fig. 141, and this shaft carries a sheave to which wires are attached for working a distant signal. Before the switch can be opened the shaft must be turned down, thus placing the distant signal at danger, and the signal cannot be cleared until after the switch has been closed.

Figure 246 shows a double ground lever stand for operating one or two switches in connection with one or two signals, the levers being so interlocked that the signals cannot be cleared until the switch lever is thrown

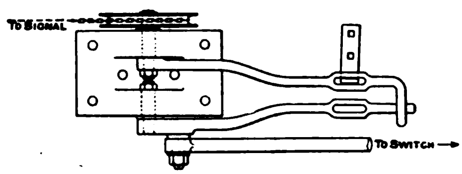


Fig. 244.—Switch and Signal Ground Lever.

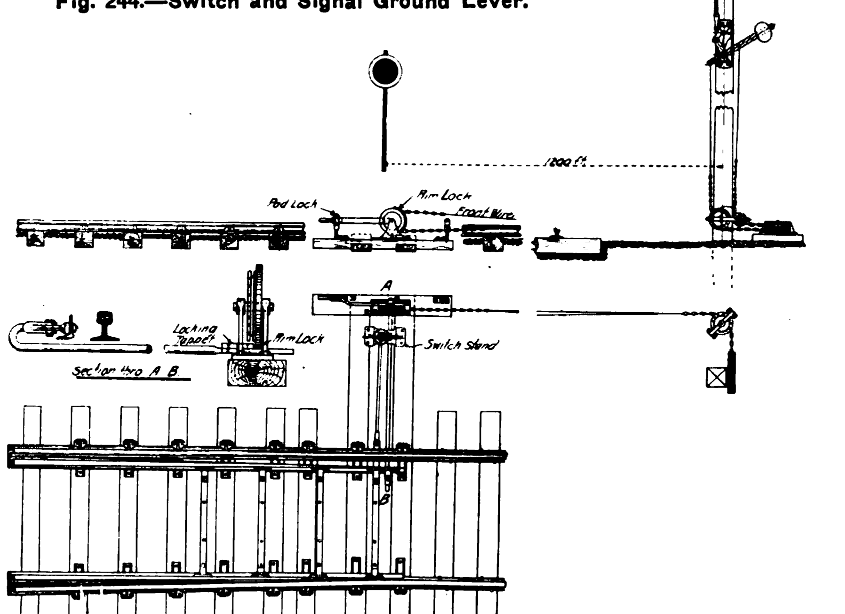


Fig. 245.—Distant Signal Device for Outlying Switches, C. & N. W. Ry.

for the main track and, conversely, so that the switch lever cannot be moved from the main track position until the signal lever has been thrown entirely to the danger position. It is in use on a large number of roads, including, among others, the Chicago, Rock Island & Pacific, Chicago & Northwestern, Michigan Central, Atchison, Topeka & Santa Fe, Wisconsin Central, Pittsburg, Fort Wayne & Chicago, Boston & Maine, Boston & Albany, New York Central and the Central R. R. of New Jersey. The arrangement is what is known as butt locking, in which two locking dogs or pins follow in grooved discs and are actuated by springs, so that the action of one lever locks the other lever fast in each position of the switch. It will be observed that a projecting lug on the signal lever extends over the switch lever and straddles the lock bracket, so that the interlocking cannot be strained by an ignorant or malicious use of the switch lever. As it appears in the figure, the switch lever operates two switches and the signal lever two signals, as at a crossover. In the case of a misadjustment of the switch connection it would, but for another device, still be possible for the signal lever to be freely operated in spite of the fact that the switch points might not be thrown entirely home. This danger is overcome by the use of a flat bar connected to the switch rails and adapted to engage

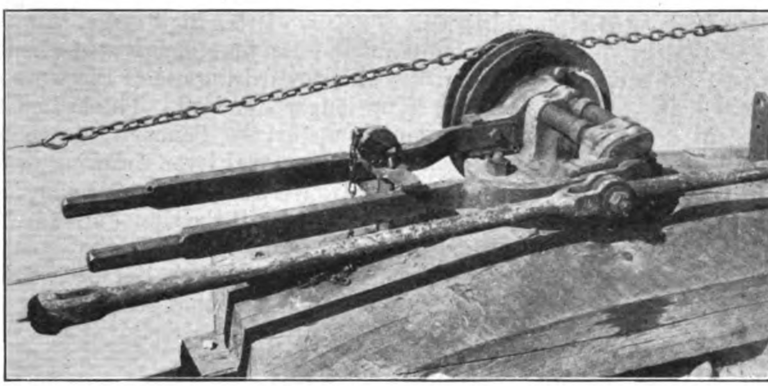


Fig. 246.—Double Interlocked Ground Lever Stand.

the wheel of the signal lever in a way which insures that the switch points shall be tightly closed for main track before the signal lever can be moved and the signal for that track cleared. The device is so strongly made that it will prevent the switch from shifting from its intended position in event the connection with the switch lever should break.

In switch protection work the largest practice is to employ two signals—home and distant—with a lock rod so engaged by the interlocking mechanism that the signal lever cannot be put in the clear position until after the switch points have been thrown entirely home. Figure 245 shows a device used on a number of roads in connection with facing points, designed to use with existing switch stands of any pattern. As shown in plan and elevation, the signal lever operates a sprocket wheel which actuates a chain connecting with the wires operating a semaphore signal placed 1200 or more feet distant. On the sprocket wheel there is a rim, called the "rim lock," extending half way around the same. Attached to the near switch point there is a lock rod which extends under the sprocket wheel, and on this rod there is a "locking tappet" which abuts against the rim lock in every position of the signal lever except that in which the signal is moved entirely to danger. It is plainly seen, therefore, that the switch stand cannot be thrown to open the switch until after the signal has been placed to danger. Conversely, the locking tappet will not permit the rim lock to pass and the signal lever to be thrown to clear until after the switch stand has been thrown entirely home to the main track position of the switch. The semaphore blade is operated through a device on the pole which allows for two inches of expansion and contraction of the signal wire. This is considered an effective substitute for a wire compensator.

The arrangement employed on the Michigan Central R. R. and the Pennsylvania R. R. is a distant semaphore signal operated by double wire from a signal lever at the switch. For a home signal the Michigan Central uses a semaphore also, but the Pennsylvania uses in some places the semaphore and in others only a low combined target and lamp (Engraving *F*, Fig. 139) attached to the switch. The distant signal lever is attached to a horizontal shaft which works a "cam lock" on the switch point rail. This device consists of a lug which is turned up by the shaft against the inside flange of the point rail in its normal or closed position. It thus acts as a stop which will not permit the switch to be thrown until the distant signal has been moved to danger, and after the switch has been opened the lug is under the base of the point rail and the signal lever cannot be moved to clear the signal until the switch has been properly closed. Formerly a high revolving target, arranged on a braced stand, as in Fig. 247, was used a good deal on this road. The use of this high target was due to the installment of apparatus at points where that device was already in service. The tendency, however, has been toward the use of the semaphore, and the high revolving targets are no longer standard. The switch stand shown in the figure is a device gotten up by the Pennsylvania company, and consists of a ground switch lever with a signal lever throwing over and across the same. The two levers are controlled by a disc interlocking device which prevents the switch lever being thrown until the signal lever has been thrown into its extreme position for danger; and, vice versa, the signal lever cannot be moved to clear the signal until the switch has been properly closed. The Michigan Central road employs the double ground lever inter-

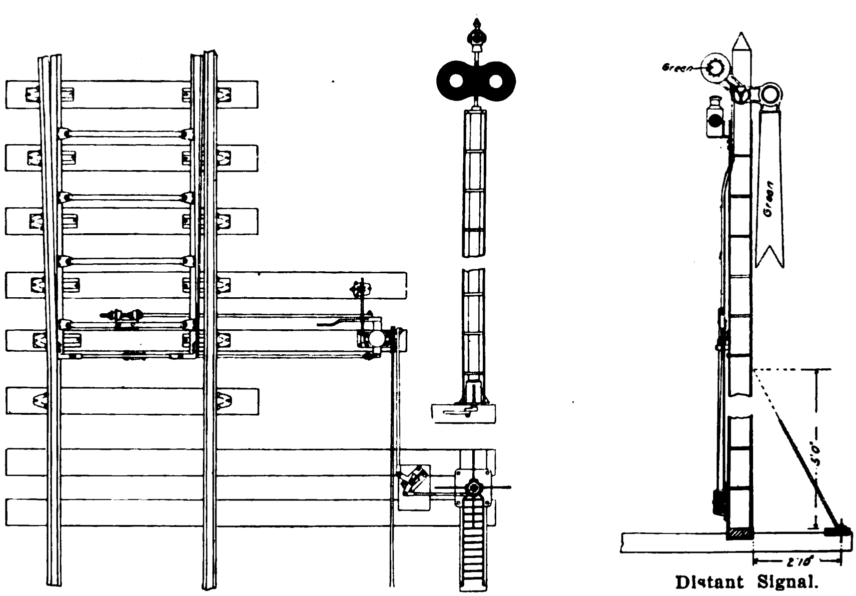


Fig. 247.—High Switch Target and Distant Signal Operated by Disc Interlocking Ground Lever Stand.

locked stand shown in Fig. 246, just described. The Chicago Terminal Transfer road uses apparatus similar to that of the Pennsylvania company, with semaphores for both home and distant signals. The interlocking stand is placed at the foot of the semaphore post instead of a few feet therefrom, as it appears in Fig. 247.

In place of the ground levers the device operating the switch and signals sometimes consists of a framed interlocking machine with upright levers, placed on the ground near the switch. On the Lehigh Valley R. R. facing-point switches are operated in connection with distant signals by a machine of this description. There are three levers: one operating a signal distant about one-half mile from the switch, another operating a signal some 500 or 600 ft. distant, and another operating the switch and a target actuated therewith. The location of the two distant signals in respect to their distance apart, and from the switch, depends upon the physical conditions respecting curvature, adjoining obstructions, etc. In operating the switch the distant signal lever must be thrown first, placing that signal at danger, or in what corresponds to the "caution" position of a distant signal in crossing interlocking. This releases the near signal lever, which is thrown next, thereby releasing the switch lever, which is thrown last of all, setting the switch and placing the home signal at danger. In closing the switch for main track the reverse order of operations must be followed; namely, the switch lever is thrown first, then the near signal and finally the distant signal.

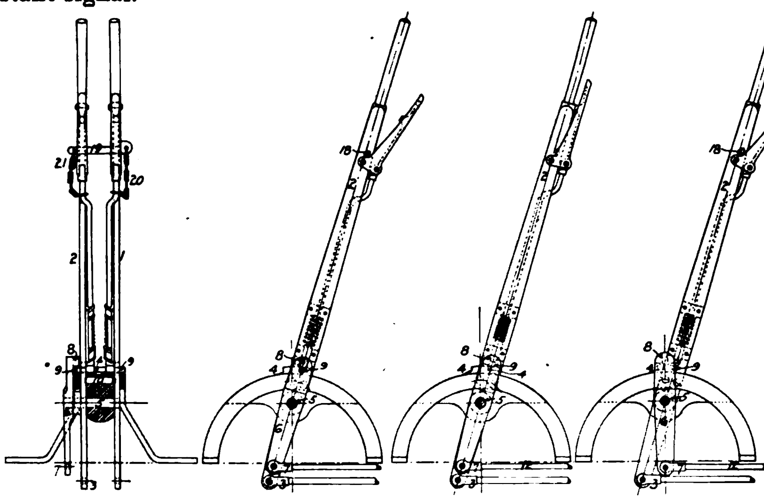


Fig. 248.—Interlocking Switch and Signal Stand, N., C. & St. L. Ry.

On the Nashville, Chattanooga & St. Louis Ry. ground-frame stands with interlocking levers are extensively used to work distant signals in connection with facing-point switches, and by means of an auxiliary lever a stiff connection is had while the switch is being thrown and a spring connection is maintained at all times while the switch is locked. This stand was designed by J. W. Thomas, Jr., general manager of the road, and is shown in Figs. 248 and 249, various parts of the apparatus and different positions of the levers being denoted by the sub-figures 1 to 7. By making a stiff connection while the switch is being operated, it must be thrown home before the switch lever can be latched; and the stiff connection being broken when this lever is latched, leaves the switch free to move to the proper position, against the Lorenz spring, should a train trail through when it is wrongly set. The stand has two levers for manipulation, lever 1 being used to operate the distant signal. Figure 1 is a rear view. Figure 2 is a side elevation showing lever 2 and auxiliary lever 6 in their normal position. If desired, a third lever can be added to operate the switch target 30, Fig. 5. Ordinarily, however, the switch target is coupled direct to the points, as shown in the figure. Levers 1 and 2 are latched in a quadrant at 4 and are pivoted at 5. On pin 5 is also pivoted the short auxiliary lever 6. The lower end of this lever is attached to the switch connection at 7, this connection being a rigid one. When latch 9 of lever 2 is raised (Figs. 3 and 7) it engages with notch 8 on lever 6 and a rigid connection is established between the switch lever and the switch. If lever 2 is now reversed and there should be an obstruction between the point and stock rails it would be impossible to latch the lever in its reversed position. The lower end of lever 2 is connected with the points by spring rod 14 (Fig. 5). Should a train trail through the points while they are wrongly set they would be moved over and the Lorenz spring 15 would be compressed; and as the upper end of auxiliary lever 6 would be disconnected from latch 9 of lever

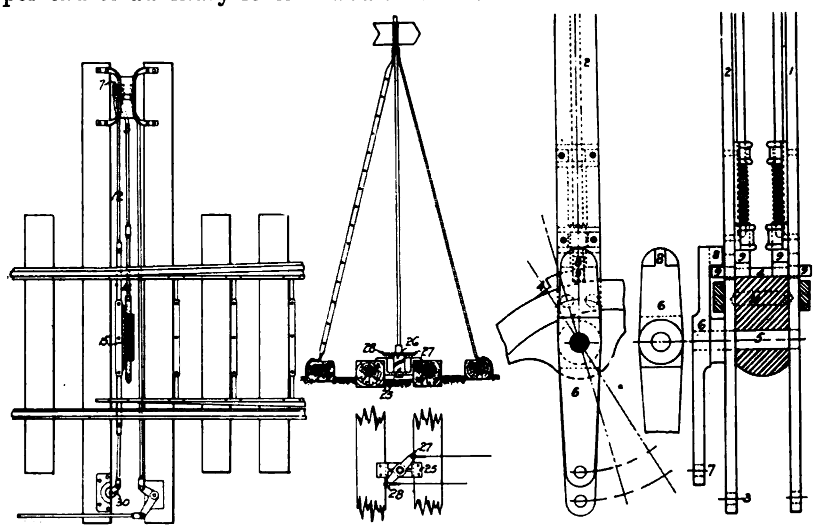


Fig. 5 Fig. 6 Fig. 7

Fig. 249.—Interlocking Switch and Signal Stand, N., C. & St. L. Ry.

2, lever 6 would be free to move and would assume the position shown in Fig. 4. After the train has passed, spring 15 will force the switch back to its place and lever 6 will assume its original position, as shown in Fig. 2. It is thus seen that when lever 2 is latched in either its normal or reversed position, there is but one connection with the switch; i. e., a spring connection; but the moment lever 2 is unlatched, there are two connections between the stand and the switch—one a rigid or stiff connection and the other a spring connection.

Levers 1 and 2 are interlocked by means of pointed pin 10, Figs. 1 and 7. Each lever has a countersunk hole into which pin 10 engages, it being so arranged that it is impossible to move lever 2 from its normal position until lever 1 is fully reversed, the reversal of lever 1 putting the distant switch signal at caution, showing that the switch is either unlocked or set for the siding. The starting of lever 2 from its normal position crowds over pin 10 and locks lever 1 in its reversed position, the lever remaining so locked until lever 2 is latched in its normal position again. To prevent the levers from being handled by unauthorized persons, they are provided with slots, 18 and 18′, through which passes a key 19 (Fig. 1) having the necessary chain and lock. The distant signal shown in Fig. 6 is used with this stand. The bottom casting 25 is bolted to the foundation and the target shaft is attached to top casting 26. This casting is provided with arms 27 and 28, to which the front and back wires are attached. Both castings have inclined surfaces, the lower part of 26 fitting into 25, so as to act as a guide for the lower end of the target shaft. Should the wire break, casting 26, target shaft and target drop of their own weight, the inclined surfaces revolving the target a quarter of a turn, thus making the signal automatic, in that is goes to caution if the connections holding it to safety are broken.

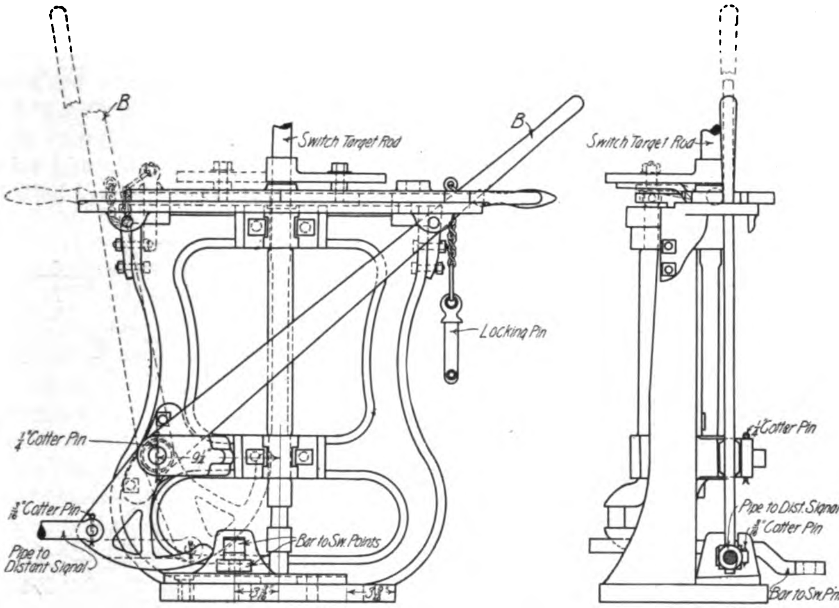


Fig. 250.—Switch Stand with Lever for Distant Signal, L. S. & M. S. Ry.

The protection of high-speed trains against the misplacement of facing-point switches on the Lake Shore & Michigan Southern Ry. is by a distant semaphore worked by a lever attachment to the ordinary switch stand, arranged to be interlocked with the switch points. The standard switch stand of the L. S. & M. S. Ry. consists of a cast-iron frame supporting a vertical shaft, with a horizontal lever throwing 180 deg. for a single movement of the switch (Fig. 250). The banner or target of this stand is of ordinary pattern, consisting of a rectangular blade painted red to show the position of the switch when set for the siding, and a circular blade painted white to show the position of the switch when set for main track. The rod for the target is separate from the main shaft of the stand or that which is connected with the switch points, and is made to turn through the necessary 90 deg. by being connected with the switch stand lever by a slotted crank (*E*, Fig. 252). The arrangement for throwing the distant signal consists of a lever (*B*, Fig. 250) pivoted to a casting bolted to the lower part of the stand, and a locking bar or lever (*A*, Fig. 252) lying horizontally on top of the stand and centered on the target rod. At the bottom of the signal lever there is a sector-shaped arm of $8\frac{3}{4}$ ins. radius which engages with a notch on a locking bar connected with the switch points when the switch is closed for main line and locked. The point rails are thus locked in position by two devices; namely, by the switch stand itself and by the signal lever; and the signal lever is in turn locked in position by the horizontal locking lever, which is secured by a padlock. The locking lever arrangement is shown in detail in Fig. 252. The upper engraving shows the position of the parts when the switch is set for main track and all levers locked. It will be observed that the first movement possible in the order of the locking is that of the locking lever *A*, but before the switch stand lever can be thrown the switch points must first be unlocked by throwing the signal lever *B*. The position of the signal lever corresponding to the danger or "caution" position of the distant semaphore is shown in the lower engraving of Fig. 252 and in Fig. 250. The normal position of this lever is shown in Fig. 251. In starting to close the switch the signal cannot be cleared until the switch points have been thrown to the home position, bringing the notch of the locking bar of the switch points opposite the sector arm of the signal lever, and the pin cannot be inserted (*H*, Fig. 252) for locking the stand without first moving the locking lever to secure the signal lever in the normal position. The arrangement is simple and substantially designed. The parts are all of malleable cast iron, and are bolted

Fig. 251.

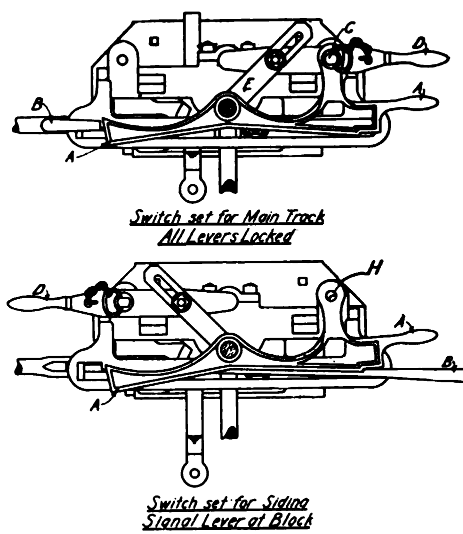


Fig. 252.

in position without changing the old stand as it is found in service and without taking the old stand down. The connection between the switch stand and the distant signal is made either by means of wire or by pipe line, the latter arrangement being the one shown in Fig. 250.

There are several designs of interlocking stands other than those described hitherto. The Gibbs stand resembles very much in general appearance the ordinary upright stand with closed frame. The connecting rod is not actuated directly, as by a crank of common form, but by a "motion plate," which is essentially a horizontally-operated cam. On one side of this cam there is a segment of a gear wheel with 17 teeth, which engages with a grooved gear wheel, around which a chain is passed and connected to the signal wires. Starting from the closed position of the switch, the gears engage and move the signal to danger during the early part of the throw, but the cam does not operate the connecting rod to move the switch. During the later part of the throw the gears disengage and the connecting rod is moved by the cam. In closing the switch the reverse order of movement obtains and the switch is moved entirely home before the gears engage to clear the signal. In the Allentown Rolling Mill Co. interlocked switch stand there are two levers attached to an upright frame: one to work the distant signal and the other the switch and home signal, the latter being carried by the stand. Both signals are semaphore blades of the common pattern. One of the levers takes the form of a T-crank, with the signal wires attached to the two arms. The two levers are interlocked by a vertical sliding bar which abuts against an arc on the top of the T-arm of the distant signal lever. The switch lever is engaged with this sliding bar, and as soon as the distant signal lever has been thrown to the danger position the bar is released, permitting the switch lever to be thrown up, thereby pulling down the sliding bar and hoisting the home signal blade, to which the sliding bar is attached. This movement locks the distant signal lever, which cannot be thrown to clear that signal until after the switch has been closed, the sliding bar raised and the home signal cleared.

The Elliott electrically-locked switch stand, designed by Mr. W. H. Elliott, while signal engineer of the Chicago, Milw. & St. Paul Ry., is arranged to put the control of the switch in charge of a telegraph or signal operator at any distance away, enabling him to prevent the use of the switch within a desired time interval previous to the arrival of a main-line train or to prevent a train from leaving a siding or branch line whenever it is desirable to hold it. The principal feature is an electro-magnet which locks a slide controlling a lock rod or plunger which passes through a lock bar attached to the switch points. Unless the magnet is energized the rod cannot be withdrawn and the switch opened. Upon opening the switch the current in the circuit is broken and an indication is given in the distant telegraph office or signal cabin. Upon closing the switch the circuit is again made and the proper indication given at the distant point. The switch lever cannot be placed in its normal position and locked unless the lock rod drops to its proper position through the lock bar, thus insuring that the points have been thrown entirely home when the indication is received that the switch has been closed. At the back of the switch stand there is a box with a glass-covered opening, in which is an indicator to show when the lever which lifts the lock rod has been released.

Switches thrown by ordinary stands are sometimes controlled by a lock operated from an interlocking tower in the vicinity, and this lock is interlocked with a distant signal also operated from the tower. With such means of protection the distant signal must be put to danger before the main track can be opened. Where automatic electric block signals are in service the connections are such that the opening of a switch sets the home and distant signals controlling the block to danger and caution, respectively. The arrangement consists of a circuit breaker connected with the switch points by means of a rod and crank and enclosed in a cast iron casing or box which is lag-screwed to the headblock. This device is commonly known as a "switch box" or "switch instrument," and is in circuit with the electrically-operated signal at the entrance to the block, or is cut into the track circuit. To make doubly sure that the signal will go to danger when the switch is opened, both the track circuit and the signal circuit are sometimes run through the switch box. The track circuit is also carried through the rails of the side-track as far as the fouling point, so that the signal will show danger until cars are entirely clear of the main line, even though the switch is closed. The opening of either switch of a main-track crossover puts the signals at stop in both directions. It is now extensively the practice, with switches located in the middle of a block or some distance from a block signal, to place a visible or audible indicator at the switch, so that trainmen may know, before opening the switch, whether a train has passed the signal controlling the block, or rather a point 1000 ft. or some safe distance in advance of that signal. A miniature semaphore arm, in a glass-covered case, or a gong bell to ring when a train is on the circuit, are appliances that are commonly used for this purpose.

The switch box is also used, sometimes, with facing-point switches where block signals are not in service. The throwing of the switch opens a line circuit and brings the distant signal to the danger position. In some installations, as above explained, the connection between the switch box and the distant signal is through a track circuit and relay, in such manner that the throwing of the switch, in addition to opening the circuit of the line wires connecting with the signal, shunts the battery from the relay, thereby de-energizing the relay and opening the circuit there. By this arrangement the circuit is opened at two points, namely at the relay and at the switch box, thus making the operation of the signal doubly sure. On the Fitchburg R. R. it has been arranged with installations of this kind to have the track circuit control a lock on the lever of the switch stand, so that after a train passes the distant signal at clear and enters the track-circuit section, the switch cannot be thrown until the train has passed the switch.

On some divisions of the Cleveland, Cincinnati, Chicago & St. Louis Ry., the Baltimore & Ohio R. R., and on some other roads, interlocking machines are installed at block signal towers to work the switches of crossovers and passing sidings. These towers are usually located at such sidings, and by putting the control of the switches in charge of the towerman the trainmen are relieved of the duty of handling the switches. The arrangement saves time, and, as the switches are interlocked with distant signals, the safety of the train operation is unmistakably promoted. The interlocking plant at each tower is usually small, there being but a few switches under control, so that the extra duty imposed upon the tower operators is not at all burdensome.

The practice of arranging distant switch signals varies with the conditions and the requirements to be met. On double track a single facing-point switch needs protection in one direction only, and usually there are but the home and distant signals, although an intervening signal is sometimes provided at a curve. On single track, signals in both directions are sometimes provided: but if for only one direction, that for trains which approach facing the switch is of course the one chosen. If the switch be at a junction, signals would evidently be displayed on both tracks. Derails in side-tracks may be interlocked with the main switch and signals and a dwarf signal interlocked with the rest may be used to indicate the position of the derail. For a facing-point crossover on double track signals would be displayed in both directions and the stand may be placed midway the crossover, so as to throw both switches. On single track where there are two switches near together, but facing in opposite directions, signals must be displayed in both directions; and these may be arranged so that the throwing of either switch moves both signals. Two distant signals can also be made to serve a crossover on double track and a near-by siding on one of the tracks, the arrangement being to have the movement of any one or all of the switches throw the proper signal or signals. Where ground-lever interlocking machines are provided it is usual to have a lever for each switch and each signal, the locking being so arranged that each lever can be thrown only in its proper order. It is feasible, however, to connect two switches or two signals to each lever.

CHAPTER VII.

TRACK MAINTENANCE.

85. Raising and Tamping Low Track.—The expense of keeping track in smooth surface, commonly called "surfacing," is greater than that of any other item of track maintenance. The exact, or even approximate, ratio of the cost of surfacing to the average expense of track maintenance, in general, is a difficult matter to get at; and figures bearing on the subject obtained from a single road or railway system are not a satisfactory criterion, because varying roadbed conditions and qualities of ballast are paramount considerations, and different companies have different ideas as to the relative amount which should be expended on appearances, such as policing, landscape gardening, etc. Reports of the Interstate Commerce Commission show that the expense of track maintenance averages 15.67 per cent of the total operating expenses of railways. The ratio of these two accounts has remained very nearly constant from year to year. The average expense of "repairs of roadway" is 10.66 per cent of the total operating expenses, or 68 per cent of the total expense of track maintenance, the ratio of these accounts also remaining very nearly constant (remarkably so) from year to year. In the classification of the Interstate Commerce Commission the account "repairs of roadway" covers all expense of maintaining the track and right of way except cost of material in renewals of rails, cost of material in renewals of ties, repairs and renewals of fences, road crossings, signs and cattle guards. It should be noted that repairs and renewals of culverts is not included in the above statement, that item being classified with repairs and renewals of bridges. It is next to impossible to segregate the item of track surfacing from other matters included in the account "repairs of roadway" in the reports of the Commission. It is certain, however, that the expense of surfacing constitutes a very large share of the account "repairs of roadway," and, being the chief matter in maintenance expense, it must relatively receive a great deal of attention.

Estimates on the expense of surfacing track, and figures commonly reported from individual roads, run from $95 to about $210 per mile of track annually. Some roads handling light traffic on track ballasted with earth, sand or other poor material expend a good deal of money on track surface, the account sometimes running as high as 150 to 170 days' labor per mile of track per year. On roads of heavy traffic, operating under average conditions of roadbed and track, the figures are not so variable, and in view of the dearth of information on the subject in publications of general circulation, I have gone to considerable pains to investigate. The accompanying tabulation has been compiled from the records of eleven railroads or divisions of the same, the road in every case being ballasted with gravel and the track surface maintained in first-class condition. The figures cover only one item, namely the expense of raising and tamping old track to maintain it in surface. The expense of lining track, reballasting or shimming is not included in any case. Five of the roads (A, B, D, G and J) are double-track lines, but the expense figure in each case refers to one mile of single track, and the traffic data refer to the train movements over one track; or in one direction only, in the case of the double-track roads. The data in every case cover only main track and main line, no branch-line track being included. The roads, except Road C, are generally distributed over the northern part of the United States east of the Rocky Mountains, where the ground is frozen during three or four months of the year. Road C is on the Pacific Coast, being part of an "Overland" route, and the track is tamped during every month of the year. The train movements in each case include both passenger and freight business, and the tonnage covers the weight of rolling stock and freight, including locomotives and cars of passenger trains. The 20 movements of Road C include 12 passenger trains; the 24 of Road E, 8 passenger trains; the 36 of Road F, 6 passenger trains and the 16 of Road H, 4 passenger trains. In the other cases the number of trains of each class is not stated, but Roads B, D and G carry a good many suburban passenger trains. In most instances the figures on the various items are average data covering a series of years.

Yearly Expense of Raising and Tamping Track.

Road	Weight of Rail.	Average No. Trains. 24 Hours.	Average Tonnage 24 Hours.	Average Expense per mile.	Remarks.
A	80	38	41,600	$142.25	201 miles.
B	90	75	58,000	$160.20	149 miles.
C	61	20	13,800	$144.00	60 miles.
D	75	41	32,900	$126.48	One Division.
E	74	24	18,000	$150.00	One Division.
F	80	36	28,400	$174.41	171 miles.
G	75 & 85	90	....	$125.00	One Division.
H	72	16	20,600	$140.73	147 miles.
I	80	Heavy	Traffic	$171.50	One Division.
J	75 & 80	Heavy	Traffic	$157.14	578.8 miles
K	70	Heavy	Traffic	$172.50	One Division.
Averages	76.7	42	30,500	$151.29	

The wages entering into the expense data average about $1.25 per day for track laborers and $1.90 to $2.00 per day for foremen. The remarkable showing of Road G, under the heavy traffic handled, is not due to low wages, for the track laborers have been paid $1.50 per day for some years. The data of this tabulation seem to show roughly, at least, that the average cost of raising and tamping track to maintain surface on heavy-traffic gravel-ballasted roads is roundly $150 per mile per year, the actual average being $151.29. The traffic carried averages 42 trains, with a tonnage of 30,500 every 24 hours, or 10 to 11 million tons annually.

In the present connection it is pertinent to explain that the term "heavy traffic," as generally understood, refers to number of train movements and not necessarily to car-load weights or weight of trains or of locomotives. The International Railway Congress in defining this term has drawn the line between heavy and light traffic at 10,000 trains over each track annually; that is, a track carrying 27 or more trains each 24 hours, or a double-track road carrying that many trains each way, is a "heavy traffic" line. For the use of maintenance of way engineers the definition of the term should convey some idea of the train tonnage. In the absence of any established standard I would suggest that 6 million tons or more, (including weight of rolling stock) passing over a track annually, or an average of 17,000 tons or more passing daily, might be considered "heavy traffic."

The forces which participate in impairing track surface are the natural ones due to the weather, such as the effects of precipitation and freezing, and mechanical forces which result from the operation of rolling stock. In well drained and well ballasted track the last named are the more important for consideration. The tendency of track to settle may perhaps be best understood by comparing its foundation with that of an ordinary building structure. In the latter case the masonry wall is laid in an excavation reaching to a firm sub-stratum. The load per square foot which earth foundations of this kind are supposed to sustain without appreciable settlement is 2 to 3 tons, at the most, but generally it is not more than one ton. Except in cuts, the ordinary bed for track is either the top surface of the ground or loose material or soil deposited thereon, and always subject to the action of atmospheric conditions, barring what protection the ballast may afford. The ballast, however, is part of the track support, and the degree to which the various kinds and qualities of the same are susceptible to the effects of weather conditions has already been pointed out. It is thus seen that track foundation or roadbed bears no comparison to building foundations for stability, and in years will settle of its own weight. As for ballast, it is at best put under the track in loose condition, and it is only by settling that it can become reasonably compact. But consider the load which the roadbed must sustain. In the case of a locomotive concentrating 100 tons on a wheel base of 25 ft. the load will be distributed over a length of, say, 30 ft. of track, or over 16 ties, which afford a bearing surface of 96 sq. ft. or less. The roadbed or ballast directly underneath the ties must then bear up quite one ton per square foot—and this with all the tremor and shock that comes from rapidly moving trains. It cannot be expected, therefore, that track laid on the natural surface or on fills will not settle, and all talk about perfect roadbed is idle. As the track must follow the settlement of the earth, which nearly always takes place more or less unevenly, the occasion for raising and tamping stretches of track from time to time is readily understood and requires no further comment.

It seems likely that a very large part of the wear and tear to track must result from locomotive operation alone, owing to the magnitude of the wheel loads and to the driving or reciprocating impulse, and no doubt the cause for irregular surface is traceable to the same source in similar degree. In the matter of wheel pressure effect upon the track it would seem that the type or class of locomotive is of some consequence, for it is true that, as a rule, the locomotives with heaviest driving-wheel loads are the ones that make the fastest speeds. An investigation of the weights of different classes of locomotives built during the years 1900 to 1902, inclusive, by 30 representative railways of the country, found the average weight per driver of 4-driver engines to be 11.1 tons; the average per driver for 6-driver engines (excluding switching engines) was 10.7 tons, and for 8-driver engines it was 10.4 tons. Five years previously the average was 9.8, 8.8 and 8.3 tons for 4-driver, 6-driver and 8-driver engines, respectively. Heavy 8-wheel passenger locomotives are undoubtedly the most severe on track surface, and the growing practice of putting 10-wheel engines into passenger service is in line with improvement in this respect. Consolidation and mastodon locomotives, which have eight driving wheels, are supposably the easiest on track surface. While it might be thought that a given number of driver loads of stated weights should produce a greater pressure effect than a smaller number of somewhat heavier loads, it must be taken into consideration that as the number of drivers decrease the distance between wheel centers increases; and that the severity of loads on the track is augmented by the distance between the points of application, since the upward flexure of the rail between the wheels permits of an uneven distribution of the load over its proportionate length of track. It would seem, for example, that 10 tons bearing on the rail at each of two points 8½ ft. apart should depress the track farther than 40 tons evenly distributed at four points along 14 or 15 ft. of rail. The work of Mr. P. H. Dudley in measuring rail stresses with his "stremmatograph," shows that as the number of driving wheels is increased or the wheel spacing decreased the stresses in the rails are less per ton of driver load. It is understood, of course, that volume of traffic, as well as weight of rolling stock, is a factor of track impairment. As a matter of illustration, the track in general service a decade ago might be considered quite safe for the heavy locomotives and car-loads of to-day, and might stand up satisfactorily under traffic consisting of a few train movements each day, but under the numerous movements of a heavy-traffic road it would be found too light for economical maintenance.

About the first work, then, which must be done after new track has been used, in order to restore it to its original condition, is to raise the low places to an even surface with the whole and hold it there by tamping. This work is unceasable, for stretches of track will not usually remain in good surface longer than a few weeks or months at a time. It may and should be prosecuted at all seasons when the condition of the ballast will permit, continuing as long as possible before the ground freezes, to get the track in good condition for winter, when the only way to do surfacing is by shimming. The urgency of other work will engage the attention of the section men at times, but the foreman should be continually watching for rough places in the track surface. The extent to which unevenness may be permitted in track surface depends, for the most part, on the degree of comfort which the company expects to afford its passengers. The rate of wear and tear to rolling stock increases very rapidly with roughness in track surface, and the schedules of the fast trains and the reputation of the road will be determined very largely from the ease of riding in the cars. It is for this reason that some railway managers with an eye to business are most particular about the track surface on those portions of the line which cover the dining car runs, aiming to keep that much of the track in smooth condition whether or not the whole road can be maintained to the same standard. Very rough track become dangerous, especially on curves, and when track gets run down the curves are the places needing first attention. When the surface on curves becomes so uneven that the bell will ring from side swaying of the locomotive, it is high time to get action on repairs, but of course track should never be permitted to get into any such condition.

It is not expected to maintain old track exactly to the rail grade stakes to which it was put when new; there could be no particular object in so doing, except perhaps for short distances each way from bridges or wherever there are foundations so permanent as to show too great contrast with ordinary earthwork regarding settlement. If a piece of track, say ⅛ mile in length, settled from the original grade stakes evenly 1 in. at all places it would be wasteful of time and effort to raise it again to the old stakes. What is meant by maintaining track to surface is to hold it to a smooth and even surface, but not necessarily to the original surface or grade line. Many foremen make a mistake in this. They have an idea, somehow, that track must continually be "tamped up;" and so they keep it going on upward. In case they find a few low joints or rails they raise "out of face" the whole stretch of track in the vicinity, instead of merely raising the low places even with the general surface. As track settles with and into the ballast the bed hardens, and as far as it settles evenly it should be permitted to remain; for it is in this condition that it can be held to good surface at least expense. As a general thing there is too much raising track out of face. Much needless expenditure and much inferior track surface result from continually disturbing the embedment at points where there is no necessity for raising the track. There must, of course, be excepted in these remarks all reference to such track as did not have at the first a sufficient quantity of ballast, and to sags in the track due to the settlement of new roadbed. Where now and then a rail or two has settled there will be places which, relatively, look high. If these high places stand at about the same surface or grade, the low places should be lifted up evenly with them, but the high places should not be raised. This is the only economical way to maintain track in smooth surface. Many times it is cheaper and better in every way to cut down portions of the track which have settled less than the rest than it is to raise the whole to an even surface with the highest. In the case referred to, if the whole ½ mile of track had settled evenly one inch, except at two or three places of only a rail or two in length, it would seem like using better judgment to cut down the few high places an inch than to raise several hundred feet of track an inch to conform to them. Under overhead structures where the headroom is near the limit of clearance the general surface of track should not be raised without permission from the engineer in charge. Matters of this kind are usually governed by the printed rules of the road department. As already intimated, the surface of track on curves should be looked after with particular care, for the reason that a low place on the outer rail of a curve or a high place on the inner rail causes a lurch which acts with the centrifugal force in swinging or throwing the car.

To bring to an even surface track which is low for a rail length or less, much depends upon the point at which the rail is raised. Generally the jack or lever should be placed under that portion of the rail which has settled the most; or else near the lowest place and toward that side which has settled the farthest away from the lowest place. To explain the latter point, suppose that a joint has settled lower than any other point along the rail, but on one side of the joint the rail suddenly dips down in a distance of 3 or 4 ft., while the rail on the other side of the joint has settled all the way gradually over a distance of about 10 ft. Then in raising that joint, a single lift at a point 2 or 3 ft. to one side of the joint may raise the whole low portion evenly, where otherwise the quarter would have sagged. The same thing may be observed in raising a rail near the middle, or "center," as it is usually called. Sometimes after a rail has been raised by lifting with the jack set at this point, it appears to hump up on one side of the jack, while on the other side it sags down. If it were not for the hump the sagged portion could be raised satisfactorily afterward; but by letting go and shifting the jack a few feet toward the sagged portion the weight of more ties hanging to the humped portion will pull it down, and the whole stretch may be brought up evenly; otherwise, had a tie been tamped to hold the place first raised, the sagged portion would then have to be raised, and the lifting might throw the humped portion down or it might not. The reason for the failure of rails to rise evenly, sometimes, when lifted about midway of the sag, is because some part, through being low, may have become bent by weight of trains, or perhaps there might be a greater weight of ballast hanging to the ties on one side of the jack than on the other side.

While a rail is being raised an experienced trackman can usually tell by the way it comes up the most satisfactory way of holding it. If on one side of the jack the rail seems to rise less rapidly than on the other side, then, if instead of tamping or blocking the tie adjacent to the jack, the second or third tie in that direction be taken, it may support more evenly the portion raised than by holding a tie near the jack. At all events one should try to take hold of the rail at such points that it will lift evenly. Much of the success of surfacing depends upon the manner in which the track is lifted and held, and a little experience will enable one to see this if some attention be given to the matter. For convenience, the man sighting the rail may designate names for certain portions of the rail, to be used conventionally. In raising or lining track, "center" means the middle point, or the portion of the rail about 15 ft. from a joint. The term "short center" is sometimes understood to refer to a portion about 12½ ft. from a joint, and "long center," 17½ ft. from the same joint. Likewise "short" and "long" quarter refer to portions about 5 and 10 ft., respectively, from the joint. Rails of 60 lbs. per yard and heavier, in loose ballast, usually need to be raised only at the joints and centers in order to get them to smooth surface.

For a year or so after track has been built, tamping, in most all kinds of ballast except broken stone or its equivalent, is better done with the shovel than with the tamping bar. Generally there are sags to be raised out soon after new track is used, requiring it to be lifted 2 ins. or more, so that the tamping bar is not well adapted. A tamping bar is efficient only where the material can be packed into a confined space. It is at its best where there is a hard bottom and the lift not more than an inch. For a lift of more than 1½ ins., on any kind of bottom, it is better to allow for settlement in raising the track and to tamp with the shovel. For a lift of ¾ in. or more, in new track, the ties should be tamped all the way between the rails, but as the space under the ties gets shallower the tamping inside the rail can be narrowed down to the width of the shovel, and finally the tamping inside the rail can be dropped altogether; because the ties which have been raised the least should settle the least after being tamped, and it is not necessary, therefore, to tamp so much of the tie in length. It is better to tamp only a part of the length each of such ties and have the work done well, than to leave it to men to tamp as much of the tie as they would in a high lift, but not quite so well. In tamping with the shovel, where the bed is not hard, men should be careful not to dig down into and break up the old bed.

In old track where the bed is hard and compacted, and where, with an ordinary amount of work done upon it the track does not generally get lower than an inch before it is raised, the tamping bar is the best tool for all kinds of ballast except dirt and broken stone. The ballast filling between the ties must be opened out in order to get under them with the tamping bar. A pick is a good tool for this purpose, using the wedge point to draw the ballast outward to clear the side of the tie. Tamping bars are sometimes made with a sort of flattened end for removing the ballast from the side of the tie, but they can not do the work as well as it can be done with the pick, nor as quickly. Ties should be well opened out directly under the rail seat, as it is important that they should be thoroughly tamped there. If the lift is not high, and particularly if the ties are not well opened out, men are quite liable to neglect the tamping in this place. It requires more time to tamp with the bar than with the shovel, but where the conditions are favorable to the use of the bar it gives much better results than the shovel. In bar tamping, the ties need not be tamped all the way between the rails; a foot to 18 ins. inside each rail is usually sufficient. The track will hold in line better if the middle of the tie is not tamped, and any open space at this point soon becomes filled with ballast jarred or washed into it. To prevent rain water from collecting in such places the space should be loosely shovel-tamped when the track is filled in. Where the lift is not more than ½ in. high the ties need not be tamped between the rails.

In stone or broken rock ballast the tamping pick is the tool to use for tamping. With this tool it is possible to wedge the track up some without previously raising it, but for a lift of any consequence it is better to first raise the track and not to try to do too much wedging. Stone ballast can be most thoroughly tamped where the lift is about 2 ins., because if the space under the tie is too shallow to admit the tamping end of the pick, or the pieces of rock are too coarse for the space, the old bottom must be broken up. In tamping near a joint, in stone ballast, the joint tie or ties should be tamped last, as the tamping usually keeps raising the track slightly, and hence the ties tamped last are the ones most solidly tamped. The practice of tamping the outer end of the tie and next to the rail, inside, more thoroughly than elsewhere, is observed, the same as in gravel ballast. The middle of the tie should not be tamped hard.

In dirt or natural soil ballast it is a difficult matter to tamp the material to compactness with any kind of a tool. The shovel handle is rather better than the shovel blade, as it makes a better rammer. When tamping in dirt ballast much allowance should be made for settlement. A pretty good way to handle low track in this material is to raise the track 3 or 4 ins. and throw the dirt under loosely to fill the space, being careful not to get too much under the middle of the ties, for fear of center-binding them when they settle. While this method may seem like a rather careless way of handling track, still, if done right, and only in advance of slow-speed trains, there is no danger. One way of going about this work systematically, so as to get the right quantity of material under each tie to afford an even bearing, is to follow a method in practice with Roadmaster J. C. Rockhold, of the San Francisco & San Joaquin Valley Ry. (Santa Fe system). The track is lifted to the desired hight and a small heap of dirt is deposited outside the end of each tie and patted down with the back of the shovel to a level with the bottom of the tie in its raised position. The purpose of this procedure is to indicate the hight to which each tie is to be tamped. Such references having been established, the track is then raisd up 6 or 8 ins. higher and the ballast is placed under the ties with the shovel to conform with the level of the heaps outside the ends of the ties. The track is then suddenly dropped. By this method the track can be surfaced when the ballast is quite wet or under conditions which will not permit tamping to be performed by any other method of work. In track where the tops of the ties are covered with filling material, as is usually the case with dirt ballasted track, it is necessary that more care than elsewhere should be exercised not to tamp the ties too solidly between the rails and make the track center bound. The reason for this difference is that inside the rails the tamped material under the ties is confined and held by the filling which reaches to or above the top of the tie, whereas on the outer ends of the ties there is not so much filling, or perhaps no filling at all, to retain the ballast under the tie and prevent it from sliding out.

Sand ballast is usually tamped with the shovel, but where it is in a dry and loose condition the track should not be lifted higher than the surface to which it is desired it should be tamped. Burnt clay ballast of hard quality may be bar or pick tamped, but if it is soft and crumbles badly in working, the usual practice is to raise the track high enough to allow for some settlement and tamp it with the shovel blade. In ballasting new track with this material the shovel blade is used for tamping it. For tamping natural soil, sand and burnt clay or gumbo ballast thick, specially constructed tamping bars, as described in the chapter on "Track Tools," are used to some extent.

As a novelty in tamping tools and in methods of track surfacing, mention may be made of some experiments in tamping ties by air blast on the New York, New Haven & Hartford R. R. during the year 1898. A Root blacksmith's blower was used, the ballast being first passed through a hand screen to remove particles too large to pass through the injector of the machine. It was found that material passed through a ¾-in. screen could be utilized, although the finer particles were worked to best advantage. After the track was raised to the desired hight, the filling was removed from the ends of the ties and the material was blown into the cavities underneath through the opening at the ends. So far as was reported officially, at the time, the results seemed encouraging. These experiments were under the supervision of Roadmaster F. R. Coates, later chief engineer of the Chicago Great Western Ry. More recently the air blast has been used by the Bessemer & Lake Erie R. R. for tamping steel ties of inverted trough section, as described in §169, Chap XI, and shown in Fig. 483A.

The man who sights the rail as it is being lifted should get far enough away to have a good stretch of rail between him and the point where the jack or raising bar is applied. Distance assists the eye to accuracy in prolonging the line of sight beyond the established points in the general surface. In heavy surfacing it is necessary to observe the train schedule, and be careful not to raise a longer stretch of track than can be tamped to hold to place by the time the next train is due. As a precaution, alternate ties should first be tamped outside the rails to make safe for trains which might come before they are expected. In a light or moderate lift the tamping of every tie outside the rails will usually hold the track up under a train movement without settling badly enough to require raising again, and if in addition to this alternate ties are tamped inside the rails there can be no question about it, for a lift of any hight. Although it is desirable to have all the ties fully tamped before a train arrives, it is not very necessary that such should be the case providing as much of the work as is above noted has been systematically completed. By bearing this fact in mind the foreman is conscious of having some leeway in case he should overestimate the amount of work that can be completed in the time available.

Foremen should observe closely to see that the ties are tamped to a uniform bearing, being particularly watchful of new men to get them to tamp wide ties thoroughly, driving or crowding ballast all the way under the ties. Each two men tamping together on old track should carry a hammer, and where spikes are found loose they should raise the tie and drive them down to the rail tightly before starting to tamp. Where the gravel is mostly fine in quality coarse pieces of rock should not be driven tightly under the ties, as they form an uneven bearing. Allowance should be made for tamping, according to the manner of tamping. It is not practicable by any means to make the newly tamped bed as hard as an old bed of ballast; hence low rails should be raised slightly above the general surface. Just exactly the allowance to make cannot be stated in general terms: an intelligent foreman can better ascertain that after he becomes acquainted with the quality of the ballast, the way the tamping is done and the reliance he can place in his men. In high lifting it is well to tamp two ties to hold joints that are being raised, as otherwise the settlement may be so great when the jack lets go as to require lifting the second time. In order to give the joint ties the benefit of a little better tamping than the other ties get, they may be tamped a trifle high, while being held by the jack or bar, and then struck down with a sledge hammer. Such practice is quite frequently followed and gives good results. Wherever tamping is done the track should be filled in the same day, to drain the water off or hold it back in case of rain, but if this work is left some distance behind the tamping operations there will always be something to set the men at in case the track raising is delayed out of hesitation to throw up a rail in advance of a train that is late. Wet weather is not favorable either to tamping operations or the results of the same, because the material is liable to be softened and slide out before it has a chance to pack hard.

Sometimes at joints which have been quite low for a long time the ends of the rails get bent, and this condition gives rise to the term "surface-bent" joints or rails. In raising a joint of this kind the quarters each side will bulge upward higher than the joint. The proper method of treatment in such cases is to raise the joint somewhat higher than would be done if it was not bent, and then tamp the joint tie or ties well, but the shoulder ties hardly enough to enable them to take the bearing they would afford if the ends of the rails were straight. In the case of a supported joint the joint tie may be thoroughly tamped, but at a suspended joint the two joint ties should be tamped hard on the side next the joint, but loosely on the side next the shoulder. After maintaining the support in this manner for some time the weight of trains may straighten the rails. Where the settlement is very low it is best not to raise the joint the full hight all at once and let trains run over it, as there might be danger of breaking the rail. It is a difficult matter sometimes to straighten a surface-bent rail in this way. It helps matters a good deal to put a new and straight splice on the joint after it is raised and tamped, for the old one may be bent so badly as not to permit the rail ends to come to their proper place. A device for straightening bent angle bars is shown and described in § 135, Chap. IX.

In raising track on straight line the level board should be used. Whenever a sag on one side is raised out it should be put level with the opposite rail. For the steady riding of cars it is necessary to have the track level transversely. Quite frequently one may find each rail in fair surface but the track out of level, first one side running low and then the other. This state of things causes the rolling stock to lean toward the low side, bringing a preponderance of pressure on that rail, from which arises a tendency for that side of the track to settle faster than the other. On roads running east and west through a cold country there is a tendency for the south rail to get lower than the other, owing to the fact that that side of the ballast and roadbed is on the sunny side and thaws out earlier in the spring. For a time after the frost has gone out on that side the ground in the shade of the north rail still remains frozen. A convenient and rapid way for section foremen to test their track for level is to find some place where the rails are level transversely and then place a level board across a hand car standing at the point, and block the board to show level. By running the car along slowly with the level board thus arranged one can form a good idea of the condition of the track respecting transverse level, and also note the points where the low rail alternates from side to side. Before using the level board to raise the low side the high rail should be put in good surface, if not already in such condition, and then the low side may be brought up by the board. By making it a practice to use the level board when raising track, foremen will eventually get the rails level transversely over their whole section; neglect to do so will sooner or later result in track out of level. On this point Superintendent W. L. Park, of the Union Pacific R. R., in an address to the section foremen of his division, advised them as follows: "In order to obtain perfection in surface it is essential to use the level. We are aware that you have a good eye, but do not strain it too much. Give the level a show and it will help you out exceedingly."

As soon as the ground settles, after the frost has gone out in the spring, the section crews should get to work at surfacing and pick up the roughest track first. This will generally be found where shimming has been done during the winter. The shims should be removed, the ties raised to the rails and the spikes driven down, the rails raised to surface and the ties tamped. As soon as the tie renewals are made the foreman should begin at one end of the section and go over it thoroughly, raising and tamping to surface all low places as he goes along. Track does not settle so much in summer as it does in the spring, but it settles in places all the while; and with the best track there will be low places enough by late in the fall to make it necessary to go over it again before the ground freezes. Very low places should always be raised as soon as found, but by working over the section thoroughly from end to end, as stated, many low places will be discovered which otherwise would be overlooked.

The surface of track near the ends of bridges should be closely watched. A low place under a rail entering a bridge will give cars a hard jolt. Joints which come on an embankment close to the end of a bridge nearly always give trouble. Where, in course of laying the rails, a joint comes this way it is a good plan to cut the first rail on the bridge so that the joint will be on the bridge a few feet from the end. Then move up a rail so that the first joint off the bridge will be a full rail's length from the first joint on the bridge. Take the piece cut off the rail on the bridge and put it in behind the rail moved up, or if it be too short, use two longer pieces. The end of the embankment, where it meets the bridge floor, should be bulkheaded tightly, so that the ballast may be retained and become compacted instead of rattling through and rolling away continually. Construction of this kind is described in detail under the subject "Bridge Floors," § 153, Chap. XI. In raising track at the end of a bridge it is well to start the spikes on a few of the bridge ties, so that the grade ties next the bridge may be raised and tamped a little higher than would otherwise be the case, thus allowing something for settlement. The same procedure applies to track at cattle pits, stone culverts and other points where the stability conditions of the track support vary widely within a few feet.

86. Lowering Track.—As already stated, sections of track for short distances may remain nearly to the original grade stakes, while long stretches each way from such portions may settle more or less evenly, so that it does not pay to raise the whole to an even grade with the little. The work of letting down track is an easy matter. First, estimate the amount of drop or fall. Then remove the ballast from between the ties and as much lower, between the ties, as the track is to be dropped. This can be done at any time, for it does not interfere in any way with the running of trains. As soon as opportunity offers, raise the track an inch or two, cut out the ballast remaining under the ties and let the track drop. By carefully estimating, it need not be dropped any or much below the desired surface; in case it should be it can readily be raised and tamped to place. If one side only is to be cut down the ballast must be removed to proper depth as far across as the other rail; otherwise, any of the old bed remaining under the ties, between the rails, will cause the side not cut down to be thrown up when the other side drops. If there is a considerable stretch to be cut down, and the force is large, the track may be raised and blocked while the work of cutting under the ties is going on. Of course, proper protection by flags should be looked after, when necessary. In case the trains run at close intervals and the distance the track is to be dropped is greater than the foreman would wish to undertake at one operation, it can be let down by stages of a few inches at a time. Where the track is to be dropped several feet the usual method is to shift it off the old bed, temporarily, cut down the roadbed and then throw the track back to the old alignment.

Another method that is sometimes followed in lowering track is to first dig a ditch on either side as deep as the track is to be let down, allowing the proper depth for ballast, and also dig out between the ties. Then when time is available between trains the track is jacked up and blocked and the ties are bunched, three or four in a place, throwing out unsound ties or such as would be discarded in the course of tie renewals, the spikes, in which should be pulled before the track is raised. The men are then set to work, some in the ditches and others in the spaces between the bunched ties, to cut down the earth core to a level with the bottoms of the ditches. If there is not time to finish the job in the interval between trains, a run-off is made, being laid out by drawing a mark along the bank of the ditch, which serves as a gage for the men to work to.

87. Lining Old Track.—Besides keeping track in vertical alignment or "surface," it must be maintained also in horizontal alignment or "line," as trackmen choose to call it. Track is most liable to get out of line where there is a low place on one rail only, since the lurching of the cars into the sag throws the track over; and low places on curves are more liable to get out of line than are low places on tangents. Track center-bound, or supported more solidly under the middle of the ties than at the ends, will rock and slide out of line, to one side in one place and to the other side in another. Insecure or springy roadbed, heaving by freezing, raising low places with bar or jack improperly set and renewals of ties, are also some of the causes for bad alignment in track. The importance of keeping track in good line, especially where trains run fast, is great; it is next in importance to keeping it in good surface. At the end of every day's tamping the piece of track worked over that day should be lined. It is well to line it before filling in, as then the ties can be moved without side friction in the ballast. Twice a year—just before the ground freezes, late in the fall, and just after the ground settles, after thawing in the spring—the foremen should proceed over their track with a gang and line out all irregularities.

While in lining only a few rails at a time three or four men may be able to throw ordinary track, in a general alignment there is no economy in using less than six men, and each man should be equipped with a bar, so that there need be no doubling up on the tools. Track is thrown easiest after a rain, when the ground has had a thorough soaking, and then is a good time to do it. In dirt ballast it becomes quite difficult to throw track when the ground gets dried out and baked hard, but in gravel the difference between wet and dry weather is not so much. When dirt ballast is wet it is difficult to get short holds with the bars or sufficient leverage to throw the track. Thus more men might be needed in a soft place than where the ballast is hard, simply because a man cannot get a hold with his bar that will stand what he can pull; more than this, ties in wet places, especially in soft material, are generally soggy and heavy to throw. When a specially difficult place of this character is found the track may usually be thrown by laying down pieces of plank or strips of wood under the rail, lengthwise between the ties, and taking short holds with the bars upon the pieces. Another way to move hard-throwing track is to get hold with all the bars under the ends of the ties and pry or loosen the ties from the ballast. Where this cannot be done lift the rail with the track jack set on that side toward which the track is to be moved, and throw at the same time with the bars: or it may be moved by taking a carrying hold with the jack alone—that is, by setting it a little pitching; although it is not a good plan to do this where the ballast is fine gravel, as it may work its way under the ties and prevent them from settling back again to surface. Likewise in sand ballast, where the track throws easily, the bars should not be stuck into the ballast at a low angle, as the lifting of the track may let ballast run under the ties. Where ballast is filled in at the tie ends it must be removed therefrom before track can be thrown. If it is loose ballast it may be jabbed out with the bars, but if it is hard the picks will be needed. In places where track is very hard to throw and ordinary methods of bar lining fail, time can be saved by "spike lining" it, which is done by pulling the spikes, lining up the rails on the ties and redriving the spikes. When the ground is frozen such is the only feasible method.

Tangents which appear to be in good alignment as far as the eye can scan are good enough. Although, for sake of appearance, it may be desirable to take out all long "swings" from tangents, still it is of no importance as affecting the running of trains. On curves the eye alone cannot be depended upon so reliably; for while there are men expert enough to sight a curve to almost perfectly *smooth* alignment, it is impossible for the unaided eye to run in long stretches of track to an *even curvature,* for the simple reason that, standing in any position possible, the lines of sight for different points on the curve cannot lie in a plane with the side of the rail head, as they can on a tangent, and hence the eye has not the points for comparison. Only a comparatively short piece of the curve (depending on the degree of curvature) can be taken in from one point of view; and as long as the curve is smooth, everywhere, an easy grading off into a curvature greater or less in degree cannot be detected. To use a poetic illustration, it may be said that a tangent in good line looks like something mechanically correct, while a curve, if it is smooth, appears to the eye like something beautiful. The test applied to a line to determine whether it is straight is that lines of sight from all of its points to the eye, either unaided or aided by magnifying optical instruments, shall appear to lie in the same plane; this is an accurate test and there is no other. But a test to determine whether or not a line is of uniform curvature or of uniformly varying curvature cannot be performed by establishing lines of sight alone; lines of sight together with linear measurements, or linear measurements alone, must be used. Hence much talk that is heard among trackmen to the effect that some men are able to sight a curve properly, for a distance, without an aid of some kind, is bosh. The best the eye can do is to get the curve *smooth,* but only relatively *even,* and here is where the deception comes in.

A curve is known to be even or circular when, for a chord of any length stretched against the gage side of the rail at different places anywhere along the curve, the middle ordinate measures always the same. This is a very simple test to perform; and when the degree of curve is known there can then be known what the middle ordinate for a string of any length should be. A 62-ft. string is the most convenient to use, since the length of its middle ordinate expressed in inches is equal to the curvature expressed in degrees. If it is found that the middle ordinate to a 62-ft. string is an inch longer at one place than at another, then that part of the curve is a degree or more sharper than the other part; and this knowledge may suggest to the eye what portions of the curve might be thrown out or in to make the curvature even. Stretch the string (of whatever length) from point to point around the curve so that one stretching of it overlaps the one previously taken by half its length; then if the middle ordinates do not vary appreciably, line it smooth and the curve will be both smooth and even in curvature, and consequently in good alignment. If the degree of curvature is not known and the middle ordinates vary considerably, take an average of all the ordinates and line the rail to that. Of course this procedure need not be followed where the curve has been re-centered instrumentally. For spiral curves reliable points of reference must be had at short intervals, or the track cannot be kept in good line.

Quite frequently the splices on curves get bent laterally. Light-weight splices are liable to behave in this manner if the rails have not been curved, especially where there is no filling at the ends of the ties. Under such conditions the rails will sometimes straighten out somewhat, making the splice bars angular or "elbowed." It is difficult to throw such track into good line; for if the joints be thrown in there will generally be sharp bends at the quarters which, if thrown in, will make the joints angular again. The rail can be put in fair line by throwing out all the centers, but it will not stay there very long. The best thing to do in such a case is to change places with all the splice bars, putting the outside bar at each joint on the inside of the rail, and the inside bar on the outside. Then, after tightening the bolts well the track may be thrown to a good curve and it will remain so, at least until the splices bend the other way. If the splice bars are not interchangeable an angle bar straightener can be used to good effect. After track has been relined it is a good plan to tighten up the bolts, as the throwing of the rails will now and then loosen a splice.

Before an attempt is made to line track it should be put in proper gage, especially on tangents. On curves, the outer rail being the one that is lined, the gage, unless it be far out of the way, cannot affect the line of the track in a way to influence the running of cars, as it can on straight line. When lining track the foreman or man sighting the rail should stand as far away from the place which is being thrown as he can see well. On curves this distance must depend largely on the degree of the curve, for one cannot sight along a rail very far distant on a sharp curve; but on tangents a man with ordinary eyesight can best observe short irregularities in line by being at least 90 ft. away, while for long swings he should be farther. Where the alignment is bad it is well to go over the track with the lining crew twice. At the first lining the man who does the sighting should stand off as far as he can see to take out the long swings, and then come up within 60 or 90 ft. and take the crew over it once more to remove the short irregularities. In a general alignment, as well as when raising track, the man who does the sighting should, as he goes along, occasionally cast a glance behind; because the appearance of the line or surface of a rail oftentimes looks differently from different directions. The man sighting should also stand with his back to the sun, for if it shines too directly in his face he cannot see the rail so well. In bright weather, track which runs north and south is not so easily sighted for lining early in the day or late in the afternoon, since at these times the shadows of the men throwing with the bars fall across the rails and bother the man sighting; the same difficulty is found during the middle of the day on track which runs east and west. When sighting for lining a long swing, as in sighting for raising a long sag, a chunk of mud or small stone placed on the rail at reference points assists the eye to establish the general alignment. In lining curves some prefer to have the men work toward the man who does the sighting, the idea being that then the track most conspicuously in view is in good line and in better position to go by than it is when the work of lining proceeds forward. It is thought that in the latter case the corrected alignment lies between the men and the sighter and is too close for convenient comparison with the point where the work is under way.

88. Tie Renewals.—A matter of first importance in the renewal of ties is to determine just what ties need to be removed; or just what ties if left another year would, by their further decay, weaken the track to the danger point. The appearance of ties in the track is liable to be deceptive, because they never rot uniformly alike. Some rot from within, some from without and some rot all through at the same time. The serviceability of a tie on curves is ended as soon as it ceases to hold a spike well, but on tangents not until the tie has so far decayed that it begins to fail as a support for the rail, which does not usually occur until after it has failed in its spike-holding power. On tangents there is but little stress on spikes in holding the rails to gage, as the side pressure from the wheel flanges is small. Moreover, at the moment of service the rails are held to place not alone by their connection through the tie, but also by a very firm temporary connection through the axles of loaded wheels. The strength of this connection is measured by the side friction possible between wheel and rail, and on tangents it is more than sufficient to hold the rails to place. Such being the case, the spikes on tangents are useful mainly to hold the rails when not in service, and the tenacity with which they are held by the ties is therefore not so important. It is a great mistake to inspect with a view to throwing out ties on tangents as closely as on curves. At the least calculation a tie can be of service on a tangent a year longer than on a curve.

The cost of ties for renewals, exclusive of the cost of distributing and laying them, averages 19.7 per cent of all expense of track maintenance, and is more than twice the cost of rails used in renewals, excluding, as in the other case, the cost of distributing and laying them. The reports of the Interstate Commerce Commission show that the ratio of the costs of ties and rails for renewals increased almost steadily, up to the year 1900. In 1895 the cost of ties for renewals was 1.97 times the cost of rails for renewals; in 1898 they cost 2.32 times as much, and in 1900 they cost 2.67 times as much, but in 1901 the ratio had dropped back to 1.87, and in 1902 it was 1.86, the fluctuation quite likely being due to continued high prices in the steel market. The cost of the rails in all cases is less the value of old rails taken up. The cost of laying ties in renewals is much greater than that of laying rails in renewing an equal length of track, as in different kinds of ballast and with different qualities of ties it may amount to from 10 to 40 per cent of the cost of the ties; and when removed there is added an inconvenience and further expense due to disturbing the bed of the tie. Such being the case, ties should be allowed to remain to the full limit of their usefulness, bearing in mind, of course, that it is usual to remove ties but once a year; and not to leave ties in the track which, although they might pass for the time being, possibly, would fall to pieces before another year. In respect to this rule there is some room for judgment, but in many cases foremen of experience, having an acquaintance with the lasting properties of the timber in question might, by carefully inspecting and retaining in the track such ties as would safely last another year, easily save the company one or two month's wages yearly and still leave not the least question or doubt regarding the safety of the track. Roadmasters should watch closely the old ties thrown out by their foremen. On some roads the ties are inspected on each section by the foreman and roadmaster together, a spot of red paint being placed on each tie to be removed. This practice makes lots of work for the roadmaster and casts a reflection upon the competency of the foremen.

As for determining just the time or stage when a tie has decayed so as to no longer hold spikes well for a curve, there is perhaps no general statement which could be taken for a rule. That matter depends somewhat on how many sound ties there may be near the tie in question; for where there are several unsound ties together on a curve the rails will spread or crowd the spikes. The usual way of ascertaining the degree of soundness of ties is the pick test, striking the top of the tie, outside the rail, a moderate blow with a pick. On curves the test should be made outside the outer rail. If the pick enters easily and a large portion of the end of the tie breaks off without much prying, the tie, if on a curve, ought to be taken out. To inspect ties on a tangent pry up on the end with a bar as though to raise the track. If the tie is so unsound that the end is springy (although not necessarily springy enough to break off) it ought to be taken out.

During the first few times ties are renewed after track has been built, there cannot be used the same discretion in tie inspection that is practicable in old track. Ties put into new track are generally more or less uniform in quality and their service begins at the same date for all. About the time decay begins, then, it becomes somewhat general, so that during the first year that renewals would really have to begin with individual ties a very large proportion of all the ties would necessarily have to be taken out at the same time. Moreover, should there be any question about the advisability of removing any of the ties as soon as a considerable number might seem to require it, another year's service would in all probability make necessary the removal of so many at one time that the breaking up of the tie beds would seriously affect the surface of the track. For this reason it is better to begin renewing at least a few, for the first time, a year before the same ties would have to be renewed were they in old track. Ties removed under such circumstances should be more or less evenly distributed, the object being to get new ties in their places where they can afford a general support the next year when the most of the remaining ties must be taken out. After two or three years of renewals it usually happens that about a certain percentage need to be taken out every year; more sound ties are kept in the track continually; and ties need not then be taken out until they can be of no further use.

The best way to change ties in dirt ballast is to pull the spikes from the ties to be taken out, raise the track an inch or so and pull the old ties out with the pick, without digging. Then, after dressing out the sides of the bed occupied by the old tie, pull the new one in on the old bed without disturbing it, unless the new tie is more than ½ inch thicker than the old one. This is the most rapid way to change ties, but it cannot be done in other kinds of ballast, owing to the tendency of the ballast to work its way under the ties, thus preventing them from dropping back to the old bed again. Where there is a sag to be raised, however, and there are ties to come out, this is by all means the method to follow. First, pull the spikes from the ties which have to be taken out, then raise the track in the sag and tamp joint and center ties, as usual, to hold it to surface. It is then but a trifle to pull the old ties out and the new ones in, and to spike them and tamp them along with the rest.

The usual method of removing ties is to dig a trench beside the tie slightly deeper than the thickness of the tie and then to drive or pull the tie sidewise into the trench and haul it out. Where the space on one side of the tie is wider than on the other the trench should be dug in the wider space, so that the new tie can be properly spaced without extra digging. The spikes should be pulled from the tie with a view to using them again and the spikes on an adjacent tie should be started, so that if necessary the rail may be raised and blocked up on a spike to give more room for hauling out the old tie. Dress out the sides of the old tie bed, and the bottom, too, a little, in case the new tie is more than ½ in. thicker than the thickness of the old tie at the rail seat. In the case of rail-cut ties considerable dressing of the bottom of the old bed is sometimes necessary. It is desirable to have the new tie fit in snugly, and it is all the better if it is a little high on its new bed; although men must use judgment in this or they may waste much time trying to get ties out and in where the trench is not deep enough to afford sufficient room. But it is a mistake to dig out a bed for a new tie an inch or more deeper than the thickness of the tie, the whole length of the bed. Where the old bed is dug out too deep the new tie must virtually lie on a new bed of loose ballast. Under the middle of the tie it is well enough to have the bed somewhat deeper than the thickness of the tie, since, owing to the tendency to center binding, it is undesirable to have the bearing at this point as firm as it is under and outside the rails. The foregoing remarks apply more particularly to gravel and other ballast of similar constitution. When renewing ties in rock ballast the old bed, if dressed out at all, must usually be cut considerably deeper than the under face of the tie. The labor of renewing ties on a middle or intermediate track of a 3-track or 4-track road, or in a yard or next to a siding, is greater than on the outside tracks, since a trench must be dug between the tracks in order to get the old tie out. To get ties out of or into the track in a narrow cut, where the bank is too close to permit them to be pulled straight ahead, the trench may be deepened between the rails, so that the outside end of the tie may be thrown up and thus take advantage of the bank slope. After the new tie has been hauled in, take the blocking from under the rails, drive down the spikes which have previously been started on the tie adjacent, hold up the new tie and shovel tamp it, where necessary, raising it high enough to allow for settlement. It is well to tamp the ties before they are spiked, as then if the former work is not well done the ties will settle when they are spiked or under the first train that passes, and the fact will be discovered. If the bed of the track is old and hard the new ties should be bar tamped after a few days, when the trains will have settled them into the shovel tamping. The consolidation of the ballast from the weight of the traffic is necessary to restore stable conditions under the new ties.

In common practice two men usually work together. They should carry a sharp pick, two shovels and a sharply-pointed pinch bar, and a claw bar should be available for each two parties. The work should be so divided between the two men that both are kept busy. In some kinds of ballast no picking need be done, in which case both may shovel out; or else one may pull spikes while the other is shoveling. One holds up the end of the tie while the other shovel-tamps it, then both together tamp the middle and fill in. Where ties are being renewed thickly or close together it saves time, when removing the ballast from between the ties, to cast it back between the new ties just put in, instead of throwing it into piles here and there, inside and outside the rails. In this way the track can be filled in as the work progresses, and the work of once handling a good deal of material can be saved. It is best to have the spiking done by one man or party. The ties should be so stiffly tamped that it will not be necessary to hold them up to the rail with a bar during the spiking. By careful work a new tie can be put in the track so close to the old bed that bar tamping can be done efficiently, but the common run of track labor cannot be depended upon to exercise the judgment that is required in taking out the old ties to permit the new ties to be put in in this manner. And then, of course, there are many places where it becomes necessary to respace the ties to some extent, and the new tie does not go in exactly in the place of the old one, and in that case it does not find a hard bed underneath. The gage should be used in spiking the new ties, and where necessary the gage of the rails on the old ties should be corrected as the crew advances. Ties may be hauled out and in with a pick. It is the easiest way to handle them and does no harm if the pick is sharp, notwithstanding that objections are sometimes urged against the practice. If roadmasters who forbid this use of the pick will personally attempt to get the ties out and in some other way for awhile (by taking hold with the hands, for instance) I feel sure that their rules to this effect will soon be repealed. The ends of the ties should be put to line on one side, measuring from a notch on a shovel or pick handle, and the spacing of the ties should be carefully looked after. The new ties should be spaced to suit as well as may be the space or spaces left vacant by the old ones. For instance, two large ties may answer where three small ties are taken out. Sometimes a small tie may be made to take the place of a large one by respacing the adjacent ties.

Wherever joint ties have become skewed by creeping rails they should be squared around as the tie-renewing crew goes along; and very low joints, when such are found, should be picked up. While the work of tie renewals is under way on sidings it is a good plan to put the track in surface, because many of the low places usually need raising so high that the old ties may be pulled out without digging. I am not in favor, however, of undertaking tie renewals in connection with general surfacing work unless the track is to be reballasted, in which case an excellent opportunity for cheaply renewing the ties is presented; otherwise, one kind of work at a time is enough. Where there are many changes of work in a day much time is lost. The foreman who starts out to "put the track in surface and final finish" as the ties are renewed can spend a great deal of time on a short stretch of track, all to no great purpose if the track has to be overhauled within a short time to tamp the new ties to a solid bed; and this is the usual experience.

An adz should be carried along to use on new ties which may be found winding, and if the bark has not been removed from the new ties it should be peeled before putting them into the track. It will pay in the end. The old ties should be piled up each evening and the right of way cleared of pieces of bark and rotten wood. To distinguish the quality of old ties, those which are to be made further use of may be piled near the track, in locations convenient for loading on cars, and the old ties to be burned on the right of way may be piled further from the track. To distinguish between ties to be used for different purposes, those suitable for fence posts, for instance, may be piled parallel with the track and those to be used for fuel or other purpose may be piled at right angles to the track. Where it can be done as well as not the old ties, for convenience of piling, should all be pulled out on the same side of the track. Old ties should be trucked out of each cut as soon as the renewing crew has worked through it.

Many methods of dividing the crew for tie renewal work are in practice. Some find it advantageous to keep part of the men digging out trenches, while the remainder follow along replacing the ties and tamping them. Others set the whole gang at digging trenches until 50 or 100 are prepared and then go back and divide the men into parties of two for changing the ties and tamping them. Where the traffic is heavy and trains run at closer intervals during some portion of the day than at other times it is well to use this time for digging the trenches, if the method just mentioned be followed. Passing trains are some hindrance to the work of changing the ties, for while on intermediate parts of the rail it may not be unsafe to permit a train to pass with a tie out, such is not the case at the joint. If the tie renewed be a joint tie or one of two going in at the same place, the aim should be to have the new tie tamped by the time the train arrives. In such cases, then, the trains have to be watched. It is a good rule not to have a tie out, in any case, while a train is passing. Whatever method is followed the men should be kept out of one another's way as much as possible. If the men are working by twos, let each party take a rail by itself. If the crew is large enough, let one man do all the spike pulling, ahead of those taking out the ties. A day's work at renewing ties where there is but little or no ballast to dig away at their ends, to get them out of the track, is 8 to 10 ties per man in rock ballast and 14 to 18 ties per man in gravel ballast. In sand or dirt ballast the work is more rapid, the number of ties renewed per man depending upon the method of getting the old ties out of the track; by the ordinary method of digging trenches the number is about 20.

There are those who recommend putting ties of the same quality, as near as may be, together, with the idea that in renewals all will be so nearly decayed alike that they may be taken out together. I regard such practice as both useless and wrong, for of ties of the same quality, apparently, some will outlast others two or three years. Hence to take them all out at the same time would be wasteful; moreover, by taking all out together the old bed is much disturbed. In my opinion the ideal way is just the opposite; that is, not to have more than one tie in a place to come out during the same season, although something is saved in labor, certainly, by taking out two adjacent ties at the same time, since only one trench need be excavated for the two. A tie which will last another year, however, should not be removed simply because a trench is already prepared for pulling it out. Such are my sentiments on the question of renewing ties out of face, and I regard the matter of disturbance to roadbed fully as important, from an economical standpoint, as the waste in timber. There is also another important consideration. In renewing ties out of face, or in patches of many ties in a place, the track, just preceding the time of renewal, must become very much weakened unless the ties be taken out sooner than they necessarily would be in renewing promiscuously. Especially would this be the case on curves. There can be no mistaking the fact that after the tie begins to fail rapidly—as is the case near the close of its life—there is in point of service a time margin favorable to the promiscuous method of renewing ties; and this must amount to at least one year, if anything. On the other hand, if part of the ties in a given stretch be renewed yearly the strength or firmness of the track structure remains at all times more nearly at an average, or practically always the same. In the nature of things this is the condition most to be desired, for it is impossible to keep sound ties in the track at all times, except at great and unnecessary expense. Putting the average life of ties at 6½ years the average number renewed in old track is only two or three ties per rail length each year, so that only a relatively small portion of the roadbed is disturbed. For this reason, if any attention at all be given to the quality of the new ties, it is better to mix the different qualities as much as possible than to group them together. As heretofore stated, where there are wide differences, the hardest and best ties should be placed in the curves.

Touching further upon the question of renewing ties out of face, it is admitted by all that in such practice many ties must be removed which could see further service. In 1897 a committee of the Roadmasters' Association of America took into consideration the scheme of making use of these partly worn ties in side-tracks. The investigation led to an adverse report, it being found better economy to use new second-class ties than ties removed from main track capable of two years' further service. The following extracts from the report give the course of reasoning pursued:

"We have a tie which in some instances will last two years if not disturbed. It is taken out of the main line and placed in side-track, where, owing to its having been rehandled, its life is somewhat impaired; and though there is less running over it, it will not last much longer than it would have lasted in the former place. Assume a first-class tie to cost 40 cents and a second-class tie 20 cents. The labor necessary to renew a tie in stone ballast will amount to about 15 cents, and in gravel about 10 cents; this includes removing the old tie, putting in the new one and tamping once. The life of a tie is taken at 7 years. In renewing out of face we will consider a tie (and there are many of them) which if not disturbed would have lasted 2 more years. The cost of this tie per year is $5\frac{5}{7}$ cents. To remove it will cost one-fourth of 10 (for gravel) or $2\frac{1}{2}$ cents. The cost of labor necessary to replace it in the side-track is 10 cents. Then, not considering the cost of handling, we have:

Cost of tie at $5\frac{5}{7}$ cents per year for two years	$11\frac{1}{2}$	cents
Cost of removal	$2\frac{1}{2}$	cents
Cost of renewal	10	cents
Total	24	cents
A new second-class tie, which would last 7 years, would cost	20	cents
Cost of renewal	10	cents
Total	30	cents

"In the former case the cost per year for side-track is about 12 cents; in the latter $4^2/_7$ cents. Hence, from this standpoint no saving is effected."

It might be added that on the basis of using a new first-class tie in side-track, lasting only 7 years, the cost per year ($7^1/_7$ cents) is still decidedly against the use of the partly worn tie. The report next deals with the interest cost on the investment for a first-class tie. At 5 per cent this item amounts to 2 cents yearly, which means that if two years of service be lost a new investment must be made that much sooner, thus adding 4 cents to the ultimate cost of the tie.

Now in certain special cases where the ties are not easily accessible for removal it pays to renew out of face—such, for instance, as under highway crossings, opposite station platforms and in tunnels. Obviously it would not pay to tear up crossing plank every year to renew two or three ties. In such places a full set of selected ties should replace the old ones each time the support begins to get poor, even if all have not run their full life. In renewing ties under a crossing the hard surface of the road or street should not be torn up to make room for hauling ties out at the side of the track. Either take up the rails to let the ties out and in or else throw out all the ballast between the ties and slue them around parallel or diagonally to the rails so as to get them out and in. Extra tamping is required at crossings. To remove ties in a narrow cut, or long switch ties where the adjoining track interferes, pull all the spikes on one rail and raise it off the ties high enough to let all the ties out on that side. At a pinch it may sometimes pay to split off the top of the old tie (where badly cut into by the rail, for example) or to cut it in two between the rails. In side and yard tracks also, where ties may be allowed to decay to a degree not permissible in main track, it may pay to renew ties out of face. If the foreman can arrange for the exclusive use of the side-track for a time the best method of renewing is to disconnect stretches of rails, pull all the spikes and throw both strings of rails clear off the ties. Then lift out the old ties, clean out the beds, replace with new ties, connect up and spike down the rails and surface the track. By watching carefully for high ties before the rails are thrown in not much surfacing need be required unless the track was previously out of surface.

The renewal of ties should begin in the spring, just as soon as the track has been gone over and brought to fair surface. It is a mistake to prolong this work all through the summer. The main essentials of good track are sound ties and smooth surface and alignment. Just after the departure of the frost the surface and alignment conditions of the track are at their worst; and since the renewing of ties is always more or less detrimental to the surface, it is not usually advisable to do a great amount of smoothing up until after the work of renewals is over. The latter should therefore be done as rapidly as possible, in order that all the new ties may be in before the track is thoroughly gone over and tamped, because it is a waste of money to spend much time tamping ties which must be taken out soon; but if the new ties are put in early this need not be done. It is better to hire extra men to push this work and then decrease the force afterward sufficiently to make up for it, if need be, than to have the work drag along. In the northern states all ties to be renewed in main track should be put in by July 1st each year, and all the better if a month earlier.

89. Renewing Ballast.—Track should be kept filled at all points, and, except in dirt ballast, there should be enough ballast on the shoulder, against the ends of the ties, to properly dress the middle of the track and the spaces between the ends of the ties after surfacing. The shoulders should be kept well filled out according to the standard form. As soon as the tie ends begin to overhang the shoulder or the spaces between the ties become only partially filled in, tamping must be done more frequently, and the track is not so easily held in line. Ballast is continually being used up in maintaining the track to surface. Whenever the track in a sag is raised, not only is ballast required to fill the space under the ties raised, but the ties to be filled in afterward are higher than they were before; hence, unless there is ballast at hand outside the tie ends (a surplus should never be left lying between the rails), there will not usually be a sufficient supply to fill in the track properly.

Broken stone ballast in time becomes foul with dirt, dust, cinders and weeds and when such is the case it should be forked over before replenishing the deficiencies. Where dirt or natural soil ballast is to be replaced by gravel, cinders, or other ballast of better quality, all the dirt should be removed from between the ties as far down as their bottoms before the new ballast is unloaded. In this way the old ballast (on fills) can be used to strengthen the shoulder, outside the tie ends, and the removal of such material will keep the ballast of good quality from getting mixed with that which is inferior. The rules of the Southern Pacific Co. for reballasting dirt track direct that where the grade stakes require a lift of less than 8 ins. the roadbed shall be dug out to get ballast of that depth under the ties, and that where the stakes require a lift of over 12 ins. the banks must be built up to such a hight that not more than this depth of ballast will be required. Where the track is to be lifted higher than the allowable depth of ballast and the roadbed is to be built up with ordinary filling, the track should first be raised and tamped with such material, so as to keep the middle of the roadbed higher than the shoulders, for drainage purposes; otherwise water which sinks through the ballast has no outlet except by the slow process of seepage through the embankment, softening the material and causing it to settle continually or to heave in winter. The cause for many a bad piece of track is a trough-shaped roadbed, the high shoulders obstructing side drainage from center. Unless an embankment is well crowned and compacted before the track is laid the tendency is to assume such a shape when settlement occurs. The practice of Roadmaster Henry Ware, of the Buffalo, Rochester & Pittsburg Ry., when renewing ballast on embankments which have settled in this manner, is to cut the shoulders down even with or a little below the sub-grade line as it stands underneath the ties. If the shoulders need strengthening, such work, called "bank edging," should be done before the ballast for renewal is unloaded. Shoulders should be replenished with dirt or natural soil and not with ballast material. The latter is the more costly and it will not remain so well in place on a slope.

Methods of handling material for ballast renewals are described and discussed in § 148, Chap. X. Before dumping ballast all spikes, bolts, splices, rails, etc., should be picked up. There is in practice to some extent a very convenient way of obtaining cinders for renewing ballast. A section of track which is in need of ballast, about a mile long, say, is selected and sign boards marked "DUMP HERE" are put up on either end of this section, on the fireman's side. As trains pass, the firemen dump their ash pans and the section men throw out the cinders as fast as they accumulate between the rails. In a little while enough cinders can be collected in this way to reballast the track or replenish the deficiency of filling material, after which the sign boards are moved ahead, or to some other point where ballast is needed. Sign boards for this purpose can be placed at two or more points on a division at the same time, and much expense in handling and hauling cinders can thereby be saved.

The work of reballasting main track which carries a heavy traffic is usually done by a large crew or extra gang. Where the lift is high in gravel or similar ballast, say 4 ins. or more, one tamping will not suffice to hold the track in even surface, and as some parts of it will need tamping the second time, a good way to plan the work is about as follows: Raise the rails up to the grade stakes and shovel tamp the ties outside and under the rails, but not between the rails. The spaces between the ties, inside the rails, may be filled in loosely and rather full and the material permitted to work itself under the ties by the jarring from the trains. In about a week the tamping crew should go over the track again, putting it in good surface and shovel tamping the ties all the way across. It may then be lined up and filled in. The advantages of this method are that the ballast supporting the ties under and outside the rails becomes compacted much harder than it does in the middle of the track, forming the firmest support where it ought to be, and in dispensing with the tamping of the middle of the ties in the first instance a good deal of labor is saved. In reballasting track it is necessary to make a run-off or gradual slope at the end of the raised portion each time a train passes, and to economize time while the work of raising is temporarily suspended the gang may be turned back and set to filling in. As already stated in another connection, the raising of a piece of track out of face presents an opportunity for the cheapest method of renewing ties.

The cost of reballasting track varies, of course, with the cost of handling and hauling the ballast and the price and efficiency of the labor in raising and tamping. The following figures are taken from carefully kept records of work in gravel, and in a general way may be of assistance in estimating labor costs. In one instance where the track was raised an average hight of 10 ins., a crew of 95 men unloaded the material and averaged 2500 ft. of track put up and finished per day, during the season. The men were divided for the work as follows: There was one gang of

50 men which raised the track and surfaced it roughly, and another gang of 45 men followed behind a day or two later, placing the track to smooth surface, lining, filling in, and dressing it up complete. These figures, it will be understood, refer to thorough work. On another railroad where the track was raised 6 to 8 ins. the average work performed by one man during the season was 40 ft. of track lifted, tamped, filled in and dressed complete, per day, including the work of a small gang following two or three days behind the raising gang to pick up the low spots and line out all the small kinks. It is a matter of common report that one man can average 60 to 65 ft. of track raised 4 to 6 ins. and completely ballasted per day.

90. Clearing Track of Grass and Weeds.—An item of quite heavy expense in maintenance work is that of clearing track of grass and weeds. There are two principal reasons making this work a necessity: first, locomotives are seriously impeded when grass or weeds get high enough to reach the wheels, for when crushed they form a sort of lubricant on the rail which vitiates the adhesion of the drivers; and more than this, grass or weeds just outside the rail wipe grease and oil from the wheels and afterward lop over and apply it to the rails; secondly, grass and weeds must be removed from between the ties in order to sight the rails for raising track; for as few as a dozen spears of grass, or two or three weeds near a rail—not to speak of a rank growth—may make its top surface at the point which is being raised almost invisible to the man sighting it. In clean broken stone or cinder ballast weeds do not usually give trouble, but they grow quite well in gravel ballast after it gets old, and in dirt ballast luxuriantly. The most common varieties of vegetation found in track are grasses, white clover and a kind of wiry joint grass sometimes called "gunbright." These varieties, it seems, will grow in track where they are not to be found in the surrounding region: explained probably by the theory that seeds are gathered up by car trucks and dropped along in places, and perhaps, too, they may be carried along by currents of air set up by moving trains. The most troublesome are the grasses and clovers, because of the tough and wiry roots. The annual cost of cutting these by hand may vary from $5 to $40 per mile, depending on the kind of ballast they grow in and the start they get. Figures commonly reported for track well ballasted with gravel run from $13 to $16 per mile, and in fertile ballast $25 per mile is not surprising. Depth of ballast is a condition of some account in the growth of vegetation in track, because in shallow ballast, although it may be clean, grasses and weeds may take root in the subsoil and grow through the ballast. Where such is the case the vegetation is hard to kill.

Attempts have been made to kill out vegetation in track and render the ballast sterile by sprinkling salt water or brine over it, but the cost of getting salt enough into the ballast to make the treatment effective renders the method rather impracticable in ordinary situations. Moreover, after the strength of the salt has departed the ground is left more fertile than before, notwithstanding that the application of a sufficient quantity of it is sure death to vegetation for a while. Permanent effects are not secured, therefore, except upon repeated applications, perhaps as often as once each year. In the vicinity of the Great Salt Lake, where very salty water can be cheaply obtained, the brine treatment has been found effective and more economical than the method of cutting the weeds by hand. An outfit that has been used by the Oregon Short Line R. R. consists of six flat cars each carrying a wooden tank of 3500 gals. capacity. The tanks are connected by 3-in. pipe and hose, above the couplers, and a sprinkling apparatus is attached at the rear of the train. It is also arranged to sprinkle the track from each car direct by means of splash boards. The best success has been with brine obtained from the lake direct. In the year 1900 experiments were made with brine produced by placing unrefined salt, in the solid condition, in the tanks and taking water from the water station most convenient to the work of sprinkling. This salt is a product which precipitates to the bottom at a temperature of 30 F. or under, and is washed on shore, where it can be easily obtained in large quantities, and at a higher temperature than that stated it can be held in solution. Experiments with this material were not altogether satisfactory.

At one time some experiments in the electrocution of vegetation in track were carried out on the Yazoo & Mississippi Valley R. R., which may be worth mentioning. A dynamo of the alternating type was set up in a box car, together with a stationary engine to drive it, the steam being supplied by hose connection with the locomotive. By a step-up transformer the voltage was raised to about 10,000. One terminal of the secondary circuit was attached to a large brush made of bare copper wires. This brush was of sufficient length to extend beyond the ends of the ties over both shoulders and it was suspended at right angles to the track from a flat car and made adjustable so as to be raised or lowered. The other terminal of the secondary circuit was grounded and the brush was trailed slowly along on the ground. Of course, the electric current found its circuit through the easiest resistance, or through the vegetation, on account of the large proportion of water contained, which, in comparison with the dry earth surface, is a fair conductor. It is said that wherever good contact was had with the vegetation every vestige of life was destroyed to the very ends of the roots, but the powerful influence did not seem to be uniformly distributed, so that it was found necessary to go over the ground a second time in order to make the work thoroughly effective. As the method seems to have been dropped it may be assumed that on the whole the experiments were not successful. Experiments have also been conducted by blowing steam into the ground from locomotives fitted up for the purpose. Such methods have been tried on the Chicago & Northwestern and the Chicago, Burlington & Quincy roads, but without the desired measure of success. The only satisfactory substitute which seems to have been found for the laborious process of grubbing grass and weeds in the track with a shovel or other primitive instrument is the oil burner. Cars equipped with this device have been put into regular service on a number of western roads where the expense of keeping vegetation down on dirt-ballasted tracks by grubbing with a shovel is a formidable figure, compared with the expense for the same work where tracks are ballasted with a good quality of gravel.

Weed-Burning Cars.—One of the earliest roads, if not the earliest, to make use of a weed-burning machine was the Minneapolis, St. Paul & Sault Ste. Marie Ry., where one was constructed on plans designed by Mr. E. A. Williams, mechanical superintendent, and first used in the spring of 1894. In the construction of this machine use was made of an ordinary flat car, on the front end of which (as it runs in service) is mounted an upright 30-h. p. boiler and pair of 7x10-in. engines. By means of a sprocket chain connection between the engine shaft and a car axle the car is made self-propelling. In order to overcome slipping due to the lopping of long weeds over the rails the two axles of the truck are connected by sprocket chain. By this means of locomotion a speed of from 10 to 12 miles per hour is easily made, as when running to sidings to meet passing trains. The water supply for

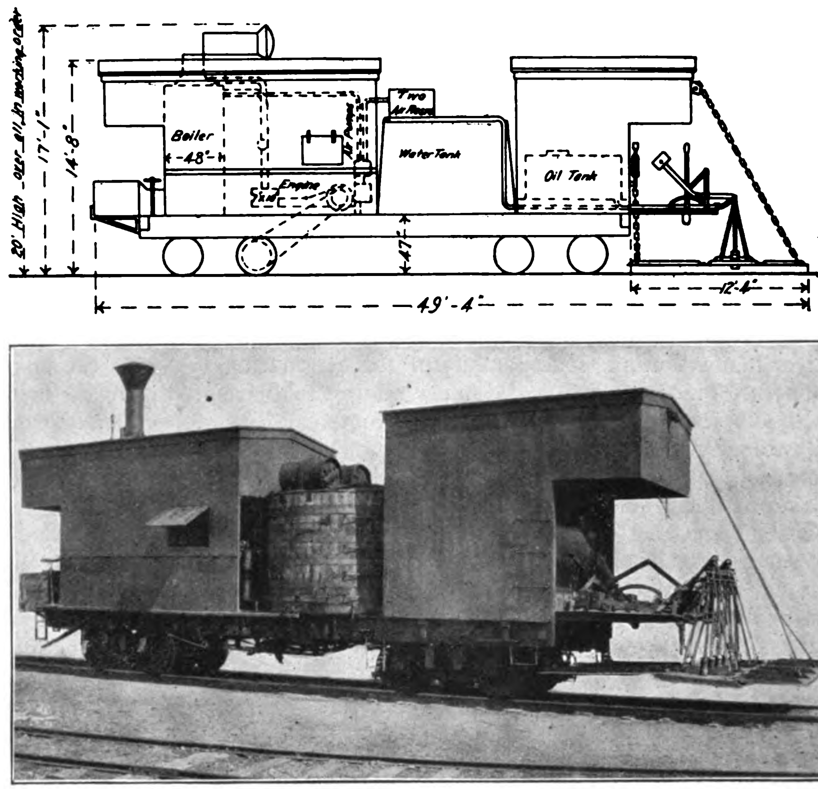


Fig. 253.—Weed-Burning Car, M., St. P. & S. St. M. Ry.

the boiler and for extinguishing fires which may be set accidentally is carried in a wooden tank in the center of the car, as seen in Fig. 253. On top of this tank there are two air reservoirs, and inside of the forward cab there are two 8-in. air pumps for creating the air pressure necessary to spray the oil into the burners. The burner rigging is suspended from a rear platform built upon four T-rails. The shield and burners are hung from the end of this platform upon bell cranks, and an old reverse lever and quadrant are used to adjust the burners to the desired hight from the rail. The burners are easily taken down when it is desired to couple the car in with a train. The tank for supplying oil to the burners is located inside the rear cab. The general appearance of the machine is shown by the reproduced photograph, while the arrangement of the machinery on the car, and the principal dimensions are shown in the line engraving. The burner shield, which is made of iron plate, covers the track around the burners, and serves the three-fold purpose of protecting the car from the heat of the burners, protecting the flame from the wind, and in confining the heat to the immediate vicinity of the ground surface. The shield has flaps, front and back, adjustable by chains attached to counterbalanced levers. There are six burners in all—four being between the rails and one outside of each rail. The burners stand $15\frac{1}{2}$ ins. apart, from centers, the burners outside of the rails being $7\frac{3}{4}$ ins. from the center of the rail. The details of these burners are shown in Fig 254, it being understood, of course, that the burner, as used on the machine, stands in the vertical position. The oil and compressed air are brought to the burner in separate pipes, the oil flowing by gravity. The car is operated

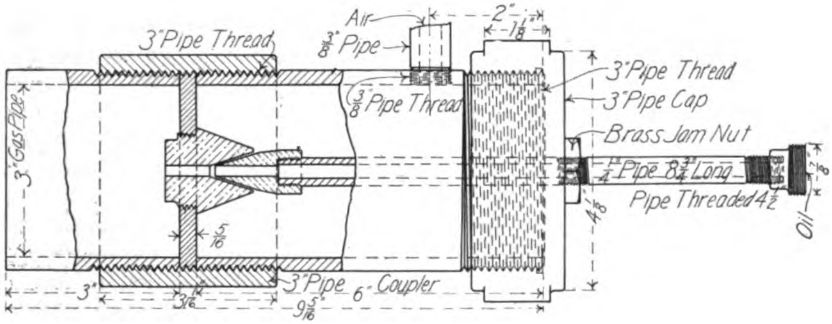


Fig. 254.—Details of Burner, M., St. P. & S. St. M. Weed-Burning Car.

by two men: one to fire the boiler and run the engine and another to operate the burners. From 10 to 13 miles of track are burned over per day, and, on an average, about 20½ gals. of crude petroleum are consumed per mile of track burned over. Ordinarily the track is burned over only once during the season, but if the burning is not started until late in the summer, or until the weeds have got a good start, or where the growth is particularly heavy, it is sometimes found necessary to burn the same ground over twice during the season. The following statement of the performance of the car in burning over 722 miles of track in one season gives the various items in detail: The total cost, including $253.49 in wages, 14,768 gals. oil at $.0389, 93,150 lbs. coal at $2.82. per ton, and $121.87 repairs, was $1081.17, or $1.50 per mile.

A weed burner used on the Chicago Great Western Ry. is arranged on a platform at the rear end of a box car (Fig. 255) which is self propelling, being driven by an 8x10-in. double cylinder mining engine connected with an axle by sprocket chain. Within the car are tanks holding the oil and other necessary supplies. There are eight burners, spaced 1 ft. apart, projecting through a metallic plate 10 ft. square, for confining the heat to the surface of the ground. The burners are distributed two outside each rail and four between the rails. The blast to the burners is furnished by compressed air at 70 lbs. pressure, supplied by two 9½-in. Westinghouse air pumps. In operation the burners are started and dropped to within about 4 ins. of the top of the rail. The car moves over the track at a

Fig. 255.—Weed Burner, Chicago Great Western Ry.

speed of about 1 mile per hour. The first time over the track the flame wilts and kills the vegetation, which is allowed to dry for several days, when the car is again run over and it is entirely consumed. Three men (an engineer, fireman and helper) are required to operate the car and burner and the section men follow along to keep fire from spreading. Crude oil is used and about 30 gallons are required per mile, each time the track is burned over.

On several other roads the weed-burning apparatus is arranged upon a flat car, which is moved over the track by means of a locomotive. In the equipment of the weed-burning car of the Northern Pacific Ry. the burners and shield are carried at the forward end of a flat car, which is pushed ahead of a locomotive. The number of burners is eighteen, arranged in three rows, with two burners in the track and two outside each rail, in each row. The shield and burners are hinged, and, by means of an air cylinder, piston and chain passed over a pulley they can be raised to a vertical position, to get them out of the way when not in use. The flat car also carries a reservoir of 16,000 cu. ins. capacity for air storage and a 1600-gal. tank for the oil supply. Air pressure is provided by a 10x14-in. "Class C" Rand compressor mounted on the locomotive pilot and taking steam from the locomotive. On its way to the burners the oil is passed through a strainer, to remove foreign matter which might clog the apparatus. The large number of burners makes the apparatus effective at faster speed than that at which the weed burners above described are worked. This car burns over about 30 miles of track per day, at a cost of $2 to $4 per mile. A weed burner used on the James river division of the Chicago, Milwaukee & St. Paul Ry. consists of a tank of 12 bbls. capacity placed on a flat car, from which pipes are led to burners at the end of the car. Of these burners there are eight—four between the rails and two outside each rail. The fuel used is crude oil, about one barrel being required per mile. The blast is furnished by compressed air supplied by air pumps on the locomotive which hauls the car; steam has also been used for this purpose with equal satisfaction. From 8 to 10 miles of track are burned over per day, and it is found that about three burnings a season are necessary in order to keep the weeds down so as not to interfere with trains. This machine will take care of about 200 miles of track. The crew necessary to operate the machine consists of two men besides the engineer and fireman—one with the burner and one to follow behind to extinguish fires which get started on the right of way outside the track. The improved machines of this road are described in §209.

The Atchison, Topeka & Santa Fe Ry. has two weed burners constructed on different ideas from those hitherto. One of the outfits consists of an iron car with an iron shield suspended between the trucks; an oil-tank car with a capacity of 4500 gals.; and an oil tank having a capacity of 800 gals., built sufficiently strong to withstand a pressure of 70 lbs. per sq. in. This tank is filled from the tank car and the oil is forced to the burners by air pressure. The shield underneath the car is 32 ft long and is provided with aprons at each side to retain the heat and prevent the flame from being blown to one side of the shield by side winds. The contrivance is put in operation by igniting the oil and lowering the shield to within 3 or 4 ins. of the rail, when the aprons on the sides of the shield are dropped and slide on the ground. When bridges are crossed the shield is lifted 12 or 15 ins. clear of the rails and the oil supply is shut off. As the oil is directed against the under surface of the shield the latter retains sufficient heat to ignite the oil for a considerable time after the oil has been shut off. In crossing culverts and cattle guards it is not found necessary to close the oil valves, since the lifting of the shield carries the flame high enough to prevent setting fire to the timbers. The amount of oil required for each of the four burners is about 8 gals. per mile. It is found that solid ties will not catch fire, but a gang of men is kept close to the car to put out such fires as may get started. The speed which the car can make depends upon the kind of vegetation worked over. In weeds not to exceed 5 or 6 ins. in hight it is practicable to run at a speed of about four miles an hour, but if the track is covered thickly with heavy, coarse grass effective work cannot be done at a speed exceeding 2½ miles per hour. It is found that only the light blades of grass and weeds are consumed, the greater portion of the vegetation being scorched, so that it soon droops and dies out. The four burners spread the flame over the whole space under the shield, which reaches about 30 ins. outside the rails. The cost of operating the car per day of 12 hours is $50, and the average length of track worked over is 20 miles per day, which makes the average expense of destroying the weeds about $2.50 per mile. The cost of the oil is not a large part of the expense, the consideration of chief importance being to keep the outfit moving. During the first year of its operation it covered more than 1500 miles of track. The cost of equipping the car with burners, building the oil tank, and the additional air pumps on the locomotives for supplying the blast, was about $1800. During another season the machine burned over 900 miles of track at an expense of $2.35 per mile.

Another weed burner used on this road was constructed by utilizing an old plate-girder turntable as the body part for an iron car. The turntable is supported by two trucks, one near one end of the table and the other about half way between the middle of the turntable and the other end, so that one end (the rear end) of the turntable overhangs the truck a considerable distance. Beneath this overhanging end there is suspended a shield 9 ft. wide and 16 ft. long, built up of two thicknesses of sheet steel spaced 6 ins. apart and filled with mineral wool to absorb the heat and prevent its radiation against the superstructure. When not in service the shield is raised 18 ins. above the rail. There are wings at the sides and at the rear end, which drag on the ground and confine the flame to the space beneath the shield. There is a cabin built upon the turntable, within which are operated three 9½-in. pumps for the air supply, taking steam from the locomotive hauling the outfit. The exhaust steam from these pumps is carried in pipes to the rear end and along the sides of the burner shield and discharged down into the ground, to quench any fires which may get started. The outfit includes a car carrying a 6000-gal. oil tank; and an extra water tender. The tank car carries a large water pump and a pump for taking oil out of stationary tanks to fill the portable one. In operation the car makes a speed of 1½ to 3½ miles per hour, according to the density and growth of the vegetation, and in light work about a barrel of fuel oil is used per mile of track burned over.

The advantage of economy seems to lie with weed-burning cars which propel themselves over the track. The daily expense of operating a locomotive exceeds that necessary to operate a self-propelling weed-burning car, and it would seem doubtful if the time to be saved in the use of a locomotive to haul the weed burner out of the way of passing trains, over that consumed by the slower moving self-propelling machine, would be sufficient to compensate for the extra cost of the locomotive operation. Especially would this seem to be the case on branch lines where the infrequency of the traffic permits the car to hold main track at comparatively long intervals. In long-distance movements, where the machine is not in service during transit, the use of the freight trains is of course available. The introduction of either type of machine must bring joy to the hearts of trackmen; for of all back-aching work the cutting of grass and weeds in track by the usual method is the worst; in a physical sense it is torture.

The almost universal, and seemingly the most satisfactory, method of disposing of vegetation in track is to cut it down as fast as it grows sufficiently high to become bothersome. This work is usually done by grubbing with the common track shovel, and on various roads it is known as "skerfing" or "sculping." The shovel seems to be the only implement in the ordinary outfit of track tools which is adapted to this work, but on humane principles something more agreeable to work with should be substituted. A steel blade about the width of an ordinary shovel blade, but shorter and thinner, fastened to a fork on the end of a long handle, on about the hang of a pitchfork, is in use to some extent for grubbing grass and weeds, one of the roads using it being the Chicago, Rock Island & Pacific. As might be expected, it is found to be a more efficient tool for

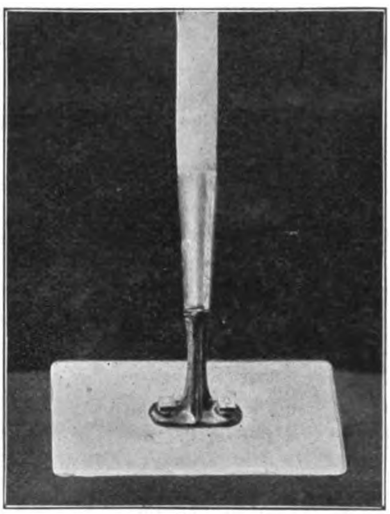


Fig. 256.—Blundell Weeding Hoe.

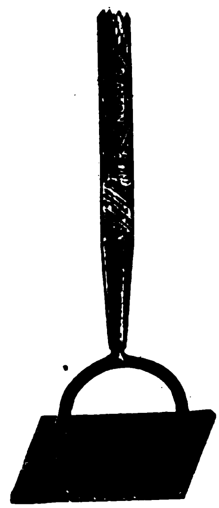


Fig. 256 A.—Weed Scuffle.

the purpose than the shovel, except in coarse gravel. A strong, wide hoe is also a better tool than the shovel for this work. A weeding hoe devised by Roadmaster E. C. Blundell, of the Chicago, St. Paul, Minneapolis & Omaha Ry., and used on that and several other roads, is shown in Fig. 256. It consists of a rectangular blade of oil-tempered steel, 9x5 ins. in size, with rounded corners. The blade is polished on both sides and has four cutting edges, beveled from top to bottom. To this blade is bolted a weighted tang, with a socket for a handle, which is 5 ft. long. This arrangement permits the substitution of a new blade when the old one is worn out. In using this weed cutter the dirt or ballast which is liable to be thrown aside in weeding with other devices remains in place in the track, or on the shoulder, and a man can stand erect and do a much larger amount of work in a day than with the ordinary track shovel, and evidently with greater ease. On the Denver & Rio Grande R. R. use is made of a weed cutter consisting of a triangular steel blade with a shank attached to a pitchfork handle. It works well in sand and dirt ballast, but not in coarse gravel, for which a shovel or heavy hoe seems best adapted. On the Evansville & Terre Haute R. R. a weed "scuffle" (Fig. 256A) is made from a piece of old shovel blade, with a long handle. The tool is made in quite large numbers at a time. The blades of old shovels are thrown into a furnace, straightened under the hammer, sheared to size, punched, sharpened, tempered and riveted to the shank. The shovels most suitable for grubbing weeds are old ones worn out for other purposes, because they are lighter. When grubbing in dirt ballast or other soft material, it helps matters along to trim the blade off squarely and then to bluntly grind it to a sharp cutting edge, but good shovels should not be ground or filed in this manner.

Vegetation in track should be cut before or during the heat of the day, so that it will wilt quickly and not need to be thrown out. Some make it a practice to scrape it into piles and throw it outside, and some give it a toss with the shovel as it is cut, thereby throwing away much ballast also. After a few cuttings in this manner the ballast on the shoulder and between the ties gradually disappears down over the bank. If the foreman is behind in his work, and there are heavy grades, he should cut the grass and weeds on the grades first. The annual contest waged against growing vegetation to maintain track in clean condition cuts into the time when much important work is on hand, and it is well to consider how far actual necessities require the work to be carried. In gravel ballast it is well to cut out as far as the gravel extends on the shoulder, or at least 3 ft. from the ends of the ties, but in dirt ballast it is hardly worth while cutting any more than the width of a shovel outside the ties, to protect them from catching fire, as this distance will usually be found sufficient for all practical purposes. Or where it is customary to burn over the right of way as soon as the grass gets dry enough in the fall, the weeds need be cut no farther than between the ties, for while burning the grass close to the track the ties can be watched. A railway company which cannot afford better ballast than dirt can ill afford to go to the expense of keeping the shoulders clear of grass and weeds. Besides, in dirt ballast the shoulder must slope from the bottom of the tie end, for drainage, and any cutting away necessarily weakens the support of the tie outside the rail.

On some roads, including the Southern Pacific, the regulations require that during the grass-growing season only so much grass and weeds shall be removed from the track as is necessary to keep the rails clear. At the end of the growing season, which is officially defined for each roadmaster's district, the grass is cut off accurately to the sod lines and after that vegetation must be kept down, between these lines, until the commencement of the next growing season. For ornamental purposes it is quite customary to preserve a nice grass line or sod line at some uniform distance from the rail. Where much weed cutting is done this grass line is liable to lead to some trouble, as the tendency is to work down the material between it and the ends of the ties and leave a shoulder at the edge of the grass to obstruct drainage. In some instances one will find channels the width of a shovel blade cut through this shoulder at intervals to drain off the water. This practice suggests that wherever the shoulders are of uniform width the grass line should be at the edge, or just over the edge, of the embankment.

Old stone ballast which has accumulated dust, cinders or dirt will grow vegetation, and when such is the case it takes an immense amount of labor to remove it and keep it down. The best way to do it is to pick up the whole filling and work it over so that the material is cleaned of dirt to a good depth. It takes time, but it is a sure method and nothing has a chance to grow in it for a long time afterward. On some roads the stone ballast is so treated every three or four years.

91. Mowing.—All grass and weeds on the right of way should be mowed each year before being allowed to go to seed. In some states the law provides a penalty for allowing Canada thistles to go to seed. The mowing should begin where the weed cutting on the shoulder leaves off, and it should usually extend to the limits of the right of way. Near wooden culverts and bridges or any kind of timber-work the grass, after drying, should be burned at the first favorable opportunity, and it is a good plan to burn over all the right of way. Vines or tall grass should not be allowed to run on or grow around trestles, telegraph poles or other timber-work. It is well, also, to cut with the shovel, the same as in the track, the grass and weeds near timber-work and telegraph poles. Around the latter it is a good plan to clear a space of at least 3 ft. radius before burning over the right of way. By taking a day when the wind is favorable the grass, brush, etc. in the vicinity of property liable to be destroyed by fire can, by watching, be burned with safety, and the danger of other fires that same year will be avoided. One way of protecting telegraph poles when burning right of way is to cut the grass around them and then throw fresh dirt around the pole. Vegetable growth at the foot of a telegraph pole hastens decay at the ground line. One way to prevent vegetation from contact with the pole is to make a small excavation around the pole and fill it with concrete. A patented device for the same purpose is a piece of sewer pipe around the pole, set into the ground socket upward, with the space between the pole and the pipe filled with screened gravel and tar or with cement. In setting new poles ordinary lengths of sewer pipe are used, but for poles already set the section of pipe is divided longitudinally into two pieces.

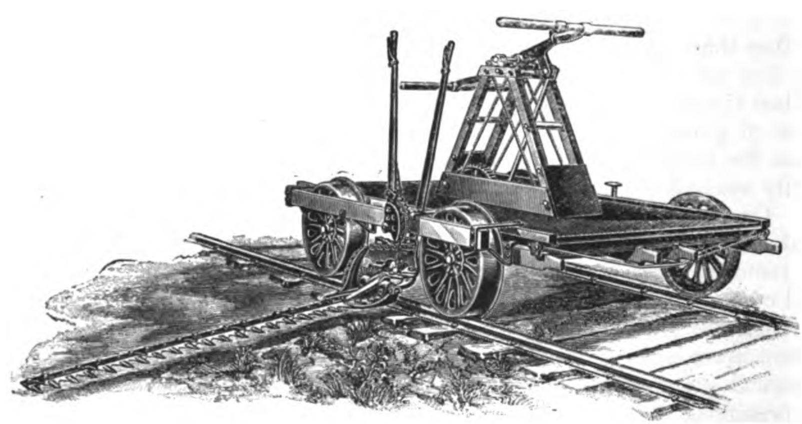


Fig. 257.—Weed-Cutting Hand Car.

In heavy grass or weeds or on rough ground the cost of mowing right of way is a considerable item—$10 to $20 per mile, $12 to $17 per mile being ordinary figures for right of way 100 ft. wide. On smooth land it sometimes pays to hire farmers to cut over as much of the right of way as possible with their mowing machines, and where there is good grass the farmers are usually willing to take the hay for compensation. In prairie country there is opportunity to make such arrangements. Some section foremen with an eye to business have prepared the right of way for machine mowing by plowing the ground, harrowing down the rough spots and seeding it with a good quality of grass, paying the farmers for the work with old ties. Each following season the farmers are then eager to mow the right of way for the hay.

On some western roads where it has been found desirable to mow only far enough from the track to clear for trains, a slow-speed hand car rigged with a side cutter bar, like a mowing machine, the sickle bar being geared to the axle of the car, is used to cut a swath each side of the track. The machine is run by a crew of four to six men, according to the density of the growth, and, when cutting, a speed of 4 or 5 miles per hour is made. Figure 257 shows a Sheffield car of this kind. The cutter bar is 6 ft. in length and is so arranged that it can be folded to a vertical position so as to pass bridges or other obstructions. The sickle bar can be thrown in or out of gear at will. The cutter bar can be adjusted to cut as low as the ends of the ties will permit and to a point 8 ft. from the rail. By a peculiar construction of the cutting arrangement it can be operated equally as well down the slope of a hill or up the face of a cut as on level ground. The weight of the car entire is 750 lbs. The car is placed in charge of one man, who looks after the mowing for a division, the crew necessary to run the machine being furnished by each section as the car comes along. Before the arrival of the car the section foremen see that old ties, stones, etc., are removed from the vicinity of the track. After the mowing season is over the cutting apparatus is taken off and the hand car is put to general use.

92. Cutting Brush.—Some railroad companies hold miles of right of way, of a width which clearly exceeds their present or future needs, for no other apparent reason than the privilege of paying taxes and cutting a crop of brush or weeds on it yearly. Around curves a wide right of way is needed, in order that the company may keep a clear space wide enough to enable trainmen to see a good distance ahead, and the usual width of 100 ft. is none too much. At public road crossings, also, and especially if the road emerges from a forest or is enclosed by trees or other objects which obstruct the view each way along the track, a wide right of way should be kept cleared. At cuts a wide right of way is necessary to provide room for snow fences, and in many cases a width of 100 ft. is insufficient. At other points, however, there is usually no need of more than 50 ft. for this purpose, and unless there is a considerable fill or cut, or a prospect of some future need of more room can be seen, there is no reason why the company should burden itself by holding a uniform width of 100 ft. everywhere, to be cut over. There is, in an extra width of 50 ft., about 6 acres of additional right of way per mile. At a cost of $2.50 to $3 per acre for brush cutting and, say, $1 per acre for mowing grass and weeds, this extra land calls for something between $6 and $18 of extra expenditure per mile, yearly. It seems almost a pity that along thousands of miles of railroad so much unused right of way should go to waste. It ought to be arranged to set the fences in closer to the track and let the farmers have the use of the land temporarily vacated .

Where the surrounding country is cleared brush must be cut the full width of the right of way in order to give an unobstructed side view from trains. Brush, when high enough, will interfere with the working of telegraph wires during damp weather, and for this reason wherever, in a wooded country, for instance, it would not be desirable to cut brush the full width of the right of way, it would be well to set the telegraph poles nearer the track than their usual location near the limit of the right of way. If set deep enough there is no danger of their falling upon the track during storms. Brush standing near the track will shade it, and oftentimes in this way it injures track by shutting out sunshine from damp places during a large portion of the day. Again, where fences are not maintained, brush close to the track forms a hiding place for cattle, horses, and other stock, from which, when frightened, they jump out and reach the track before the engineer has time to stop. It is far more sightly to cut brush the full width of the right of way, and roads on a well paying basis can do it; but on long lines through wooded and sparsely settled districts, where little business is done, the expense of cutting over the full width of the right of way every year bears heavily, and brush cutting with such roads ought, therefore, to be confined to immediate necessities only. For light brush, sprouts, etc., the brush scythe is the best tool to use, but for the heavier brush the brush hook or brush ax is best. July or August are the usual months for cutting brush. Brush cut well along in the season, or after attaining some growth, are less liable to sprout again.

93. Ditching.—The proper time to clean out ditches is in the fall, during the dry weather before the ground freezes or the winter rains set in, as the case may be. Wherever there is much material to be moved, ditches should be cleaned by the work train, especially in long through cuts. It is much cheaper to load material onto flat cars than to truck it out of cuts; besides, with the work train the material taken out can be unloaded wherever it is needed to strengthen fills, thus accomplishing two purposes with a saving of labor. If the amount of material to be moved is small the section men can do it quite well, or to expedite matters they can at least clean the ditch and scrape together the refuse in heaps before the work train arrives. All grass, weeds, sticks, stones, etc. should be cleared away so as to leave the ditch unobstructed. There are, of course, many ditches which fill frequently by washings from heavy rains in summer or by thawing in spring, so that it is not always practicable to use the work train for them, and the cleaning must therefore be done by the section men.

In side-hill cuts material taken from ditches can usually be cast across the track, but in through cuts it may be taken out on the push car, or by wheelbarrows, if the cut is not too long. There are wheelbarrows made with double flanged wheels to run on the rail, for use in cleaning out cuts. The axle of the wheel is set at a slight skew to the frame of the barrow, so that the person pushing it may walk on one side of the rail instead of astride. Aside from its special use the barrow may be run on the ground or on a plank, like any other wheelbarrow, thus enabling the man wheeling the load to dump it at desired points away from the track. For small jobs in short cuts the device is quite convenient, as it saves the time required to move a string of planks from point to point to use for a runway, such as is needed for ordinary wheelbarrows. For general ditching work, where a number of wheelbarrows are needed, it is better to use the ordinary barrow on running planks strung along on the ties outside the rail. Where it is necessary to cross the track a plank should be cut the right length to fit between the rails. Proper flangeways can be made by chamfering the ends of the plank to get them to fit under the heads of the rails. This plank may be held in place temporarily by one or two track spikes, but should be taken up in advance of fast trains and when quitting work at night. Where the view from the work is obstructed by curves or otherwise, it is dangerous to place a running plank across the rails, and even where there is a good view along straight line continual watchfulness is required. Light ditching in long cuts not deeper than 10 or 12 ft. is sometimes done by throwing the material up the bank, at one or two casts, and then moving it back out of the way; but dirt from ditches should never be thrown upon the slope of the cut or left on top of the bank, near the slope.

In cleaning out ditches the ditch should be given its proper alignment parallel with the track, or such ditches as have not previously been made straight should be trimmed up. In such work a ditch line is commonly used. The depth may be kept uniform by the use of a straightedge and level or level board, taking the rail for reference; or if the track be level the required fall may be had by allowing a certain amount of drop per rail length. To keep the ditch everywhere the same depth and shape some make use of a ditch gage, which may consist of a framework constructed of strips of board and shaped to correspond to the outline of the ditch. In use the top strip (made long enough to rest across both track rails) is held on the rail and set by the level, and the ditch is shaped to conform to the depending templet. In cleaning out a wet ditch the work should begin at the lower end, so that the water will run off as fast as the work progresses. It is important to avoid digging ditches beyond the necessary depth in places. An error of this kind is not easily remedied, for if the depression be filled up to the ditch grade line, the first hard rain will wash out the loose material and water will then stand in the ditch. Particular attention should be paid to cleaning out the surface or slope ditches around cuts, and to keep the track ditches from being obstructed by ice formed by the freezing of spring water oozing from the slopes. During heavy rain storms and when frost is coming out of the ground ditches are liable to become filled with material loosened on the slopes.

94. Shimming.—Shimming at its best is only temporary work. There are two ways of doing it, viz., shimming under the tie and shimming between the rail and the tie. The former method must be resorted to sometimes where the ground is too wet to be tamped or where no fit material is at hand with which to do the tamping, but if possible it should be avoided, as it is only a makeshift. It is cheaper in the end to throw out the wet filling and truck in dry material, if it can be had, and not to shim at all. Where this cannot be done the best way is to remove the material from between the ties, under and outside the rails, and shim for the most part with planks and boards, placing them parallel with the rails and crosswise to the ties. This manner of shimming holds much better than the method of driving short pieces under the ties lengthwise. Some will shim under the ties when the ballast is dry enough for tamping, for no better reason than that driving pieces of boards under the ties when the track is raised is more quickly done than tamping; but it is a poor plan to follow.

When the ground is frozen and the track heaved up in places there is only one convenient way of getting the rails to smooth surface, and that is by blocking or shimming between rail and tie. This is done by starting the spikes, raising the rail to proper hight and blocking it to place. The tools needed are a claw bar, hammer, pinch bar, adz, crosscut saw, handax and beetle. Blocks about 8 ins. long are cut off sound straight-grained ties, pile butts or old car timber, and out of these blocks shims of proper thickness are split to match the spaces between the rail and tie. Short blocks like these up to 1½ ins. in thickness will answer for shimming on curves, and on straight line such may be used up to 2 ins. in thickness. These shims should be split the same width as the rail base and be put under the rail base parallel to the rail, that is crosswise the tie. Some object to this method on the claim that the shims when so placed will work loose. If they are nicely fitted in and the spikes driven down again tightly to the rail flange they will not work loose; but to make sure, a 6d. or 8 d. wire nail should be driven slantwise through the shim into the tie. The shim, if thin, might for this purpose be placed the least mite skewing to the rail, so as to give the nail a hold; but if the shim is thick enough it can be toe-nailed, without projecting beyond the rail base. The nail should not be driven all the way down, but should be left so that the head may be caught by a claw hammer. The track spikes prevent the shim from swinging around sidewise and the nail prevents it from working endwise. In very extensive practice shims are placed obliquely or skewing to tie and rail, fitting between the two staggered track spikes, at right angles to the line joining them. The spikes are merely pulled and redriven in the same holes plugged, and with shims not thicker than ½ in. no nail is used to hold the shim against working out; but wherever the tie is deeply rail-cut the seat for the shim should be adzed down to an even bearing. The spikes should not be started higher than is necessary to permit the rail to be raised to surface. After placing the shim on the tie where the rail is raised the spikes should be driven home on this tie, and if the rail is surface bent and inclined to bulge up at some other point, as in the short quarter of a joint, it may be brought down even by tapping down on the spikes that have been started. No shims except the one at the raising point should be placed until the rail has been put to even surface, and then they should be driven under snugly, but without forcing to the point of lifting the rail. To fit shims to place accurately and rapidly is one of the tests of that sense of adjustments which is essential to expert trackmanship.

Some prefer to place the shim crosswise under the rail, that is lengthwise to the tie, and to secure it by pulling the track spikes and redriving them through it. To do this, holes for the spikes must be bored through the shims. The hole should be bored by an auger ⅛ inch larger in diameter than the thickness of the spike, so that the latter will not split the shim, and the holes should be spaced to crowd the spikes against the flange of the rail. This boring must be done in the block before the shims are split off, for a thin shim cannot be bored without splitting. The holes cannot therefore be bored to suit the spikes as already driven, and so this method of shimming requires that the spikes be pulled entirely out, the holes plugged and the spikes redriven through fixed holes in the shims, thus spike-killing the tie. Usually there is something of a channel or rut cut into the tie by the rail flange, so that before a shim can be placed under the rail crosswise, the tie must be adzed. The extra work of adzing, boring, pulling, plugging, and redriving spikes increases the work to many times that required to do it the other way—that is, by putting the shim crosswise the tie. By that method shims can be placed in half the time it takes to put them crosswise the rail; the tie is not injured and the work is secure. I am well aware that there are those who disapprove of this method of placing shims, but experience with both methods has taught me that if properly done it is by far the better way to do it. Shims placed crosswise the tie are more secure against splitting and displacement by derailed wheels and dragging parts than are shims placed lengthwise the tie. At suspended joints raised 1 in. or higher it is quite commonly the practice to use a long shim reaching across both joint ties.

It is quite extensively the practice to furnish the trackmen with machine-made shims, produced from waste lumber in the car repair shops or bought from manufacturers. Concerning the economy of this plan there is difference of opinion, many foremen claiming that they can do better and faster work when making their own shims. When factory or shop-made shims are used a much larger supply than is needed must usually be furnished, in order to obtain the desirable assortment of sizes. For this reason some prefer to furnish only the thin sizes from the factory—say shims from ⅛ to ⅜ in. thick—and let the trackmen make the thicker sizes themselves. Among factory shims those made of elm give best satisfaction, because they are tough and withstand pressure without splitting; and when properly fitted under the rail and the spikes driven home the rails pinch into them and hold them securely in place. Shims made by hand from almost any straight-splitting wood give satisfactory service, but red oak is considered about the best, on account of the ease with which it is worked. When shims are made by hand one man does the splitting from the blocks, waiting until the rail is raised to the desired hight before beginning on the shims for that place. After a little practice at the work men become expert, and able to estimate the required thickness so closely that accurately fitting shims can be split off rapidly. Shims should be the same thickness on both edges, and not wedge shaped, but if only a slight difference exists in this respect the thicker edge should be under the outside of the rail.

Wherever the outside rail of a curve is shimmed it should be braced. Broken splice bars answer well for this purpose, and whole bars may also be used, as they are not injured and the use is only temporary; but almost any piece of iron which has a hole through it, and which can be placed to lean against the rail, may be pressed into service; or blocks of wood may be made to do. The usual way of bracing with wood is to place a piece of board or plank at the back of the outside spike and nail it to the tie, setting two track spikes to hook over the back edge or end of the piece. By notching the piece to fit around the spike a bearing may be taken against the rail flange. It is apparent that this method of bracing is applicable only where the shims are placed lengthwise the rail; otherwise the wooden brace would have to be leaned against the web of the rail. When shimming the outside rail of curves it is well, in any case, to double-spike it on the outside, if not already secured in this manner, because the curve is all the better for being double-spiked on the outside after the shims are removed. For this purpose, spikes 6 ins. long, exclusive of head, commonly known as "frost" or "shim" spikes, can be used to advantage. In lieu of braces against the rail, where shimming is done on sharp curves, some form of bridle bar, designed for application without taking up the rails, might be used. Rails shimmed on straight line do not require bracing, since the weight of the wheels holds the rails to gage. Unless the rail is lifted more than an inch the spikes need not be pulled entirely out, but simply started up and driven down again after the shim is in place, without plugging the hole.

Where the rail is raised more than 1½ ins. on curves or 2 ins. on straight line, but not more than 3 ins., the shims should be made about 2 ft. long, preferably of plank, and placed crosswise the rail. They should be spiked to the tie with boat spikes and holes should be bored through them for the track spikes. The rail surface can then be evened up with ordinary shims. Ordinary rail braces can be spiked to these shims in the usual way, for curves. Shims 3 ins. thick and thicker should reach the whole length of the tie, under both rails, in case both rails are to be raised that high. When it comes to the use of such heavy shims it is perhaps more convenient to start the ties up from their beds with wedges and shim underneath them with pieces of plank. On some roads this method is followed in lifts of 3 ins. and higher. In adjusting the blocking to the spaces in such cases some foremen use wedges alone for some of the ties, the wedges being made from oak pieces 2 or 2½ ft. long, hacking the wedge on the top side to prevent the tie from slipping and throwing the track out of line. The appearance of wedges projecting beyond the ends of the ties is unsightly, and the arrangement is insecure, as the ties take bearing only at the end and the wedges are liable to work out. In such cases it is better to block with pieces of plank and boards of various thicknesses, shoved under the ties far enough to afford support directly under the rail. In order to avoid using very thick shims the rail is sometimes put to surface partly by shimming and partly by adzing down the high places. This practice should be discouraged as much as possible, for such injures the ties and leaves an unsightly appearance in the track as long as the ties remain.

A question which frequently arises is the proper method of shimming where tie plates are in use. With flat-top plates seated flush with the face of the tie there is no difficulty, and the shim can be placed either lengthwise or crosswise the rail, preferably crosswise, in which case it must be bored for the spikes to correspond with the punching of the tie plates. If the top of the plate is not flush with the tie face it does not seem like good practice to place the shim lengthwise the rail or at a skew with it, although some claim that thin elm shims will crush down over the edges of the plate and not work out of place. On shouldered plates it is not practicable to place the shims crosswise the rail, and if the rail seat is not flush with the tie face such plates should be removed and carefully piled where they may be had conveniently in the spring, when the shims are taken out. There is no advantage in placing tie plates on top of shims, however thick the latter; in fact it is a waste of time. As shims are intended for only temporary use the question of rail cutting is unimportant. The necessity for pulling spikes from tie plates and redriving them in the same holes, or in the same holes plugged, as is required in shimming, is a source of some trouble, for if a spike head breaks off the new spike must either drive the old stub before it or dodge and go to one side. The latter course is the one which the spike is the more liable to take. To get a good fit for the new spike in such cases it is necessary to drive the old stub entirely out of the way and plug the hole. For such work on the Michigan Central R. R. each section gang is supplied with a slender spike punch for driving the old stub down through the bottom of the tie. The punch part of this tool is $^9/_{16}$ in. square, in cross section, and 6 ins. long. The tool is also convenient for removing spike stubs from under the slots in splice bars and in the bases of switch stands, and at frogs, etc.,

All shimmed track, however the work is done, should be closely inspected by the foreman or a trustworthy track-walker at least once each day. In this connection it should be borne in mind that the parts of the track which are shimmed are not heaved, but lie adjacent to and partly on the slopes of, the heaved portions; hence the settling of the heaved portion when the frost leaves the ground leaves the shimmed portion high. At such times it is necessary to watch shimmed track very closely and remove the shims as soon as the heaved portions have settled back to place. Where very thick shims are used they should be replaced by ones of less thickness during the progress of the settlement. It is usually the case that the heaved rail will, after the thawing, settle lower than it was before heaving. It is readily seen, therefore, that after the frost has gone out, the track in such cases will remain in very uneven surface unless the shims be removed. All sound shims and extra long spikes removed in the spring should be stored for future use in or about the tool house. To avoid checking, the shims should be piled where the sun will not strike them. After removing the shims the spikes of ordinary length should, unless regaging is necessary, be driven into the tie without plugging the holes. In surfacing or ballasting track, ties on which shims may be still remaining should not be tamped until after the shims have been removed.

Wherever track heaves badly the web of the rail should be painted as a mark to identify the place, and during the following summer the roadbed should be dug out and drained or the track reballasted. The only sure cure for heaving track is to drain the roadbed and put on the proper amount of good ballast. Pockets of clay or other soggy earth under the track are a source of heaving action, and when such places are dug out and filled with better material the cavity should be drained, so that it will not hold water. In some cases of this kind the use of tile or a blind cobblestone ditch may be necessary. Two instances, happening on different roads, have come to my knowledge where the conditions did not permit disemboweling the roadbed in this manner, and the following remedy was applied: During the summer the ties over the bad spot were let down and heavy shims were placed on top of them. In the winter, when the track heaved up, the shims were taken out, thereby dropping the rails to surface.

95. Renewing and Relaying Rails.—Since the day of iron rails has passed away, occasion for frequently removing battered and broken rails from the track has also passed. Steel rails of good quality do not batter, they seldom break, and they should wear quite evenly until the head is worn out. Rails on the outside of curves wear away more rapidly than elsewhere, owing to the grinding action of wheel flanges against the side of the head; but to avoid replacing them with new rails before the rails on the tangents are worn out, it is customary to exchange places with the inside and outside rails. In many instances this work of transposition is delayed too long, or until the top bearing surface of the outer rail has been too much reduced for satisfactory service on the inner side of the curve; and on some roads it is neglected altogether.

The work of transposing rails on curves is usually done by cutting loose several hundred feet of rail in a stretch and moving the two strings of rails across the track with bars, throwing one string over the other. The rails in each string remain spliced as they lie in the track and the bolts need not be loosened or changed unless the rail head is so shallow as to allow the wheel flanges to reach the bolts; for in transposing the rails the position of the bolts with relation to the gage side of the rail is also transposed. By way of preparation for the work, it is well to pull two spikes and skip one, all along the inside of each rail, over a stretch as long as the crew can handle between trains—the whole curve if possible. This work can be done while the trains are running. The outside spikes need not be touched except where they interfere with the splice bars, but such may be pulled to best advantage after the rails are thrown over. Ties cut into by the rails will also interfere with the splice bars and at the joints they must be adzed down even with the rail seat before the rail at those places can be thrown to position. As soon as opportunity offers the two strings of rails are cut loose, the remaining inside spikes are pulled and the strings of rails are changed over. The stretch of rail thrown from the outside of the curve will be found too long for the inside, and that from the inside too short for the outside; but calculations for this difference can be made beforehand and pieces of suitable length be cut and made ready to put in. If it is desired to keep the relation of the joints on the two sides close to one of the standard methods of laying—that is, joint opposite joint (square joints) or joint opposite center (broken joints)—it will obviously be necessary to place one or more short rails in the lower side of the curve; and if there were short rails on the lower side before the change, the short rails laid after the change should be placed opposite the old short rails, now on the upper side of the curve, so as to vary the desired relative position of the joints as little as possible. As fast as one stretch of rail is thrown into the place of the other a man or two should follow and tack down spikes at the joints, quarters and centers, to hold the rail approximately to place, after which all the spikes may be driven in the old holes without plugging, except where the gage may need correcting. When renewing or transposing rails it is to some extent the custom to redrive the spikes in a new place, usually on the opposite side of the tie face from the old position, but such is wrong practice, because it cuts up the fiber of the tie without any advantage in the way that spikes are required to hold the rail. Likewise, it is a waste of time and material to plug the holes when no readjustment of the gage is necessary. As is explained more at length elsewhere, the duty of a spike is to resist side pressure from the rail, and this it can fulfill just as well when driven in the old hole without plugging as it can if the hole is plugged.

While changing or renewing rails a good opportunity is presented for making corrections in the gage or in the expansion spacings at the joints, and for righting tilted rails on the lower side of curves. Where such work is needed it should always be attended to on occasions of this kind. The necessity for looking after proper allowance for expansion when renewing rails is just as important as when laying new track. After the transposition of the rails the gage sides of the rail heads, being unworn, will be practically as good as those of new rails and the gage will be more nearly what it was when the rails were first laid, because on curves the gage is continually being widened by side wear to the head of the outside rail. Where the top corner on the outside of the inner rail is roughened or protuberant from flow of metal the precaution should be taken to have the first few trains after the transposition is made run around the curve at slow speed, for this roughened corner is then on the gage side of the outer rail, and one or two train movements are necessary to smooth it down. Unless the nuts of the track bolts interfere with the wheel flanges (which they will not do except on rails of small section) trains may be allowed to pass as soon as the sections moved over have been coupled and partly spiked, for such work as regaging and relining can be done at any time, without hindrance to the running of trains. If it is found to be necessary or desirable to change the splice bolts end for end, all but two bolts in each splice may be removed before the transposition is made and these two may be reversed one at a time, so as not to loosen the splice bars, as soon as the rails have been changed over.

In transposing stretches of rail on curves it will almost always be found necessary to move the rails longitudinally, to make a proper joint at starting, and if the track is broken-jointed the distance moved is considerable—about half a rail length. One way to do this is to arrange men along the rail at the joints, with bars, after the rail has been thrown across the track, but before it is moved into its seat at any place. In throwing with the bars the men take hold against the projecting corners of the angle plates and heave together, by the word. If, however, a work train is at hand, the locomotive may be utilized to pull the stretch of rails by attaching to one end with a switch rope and clevis. Apparently one string of rails will need to be pulled one way and the string on the other side of the track the other way; that is, one string will need to be pushed, seemingly. The pushing may be done by the locomotive, with a bumping pole; or the whole stretch of rails may be pulled a rail's length past the meeting point and the extra rail disconnected and transferred to the other end of the string. If there is intelligent supervision of the work, calculations are made beforehand, and each man understands what part he is to perform, the change can be made very rapidly and without hitch in any of the movements.

On a good many roads rails for curves up to 3 or 4 deg. are laid without curving, straight rails being sprung to the curve. After the outside rail on the curve becomes much flange worn it is sometimes taken up and reversed in place, to bring the good side of the rail head on the gage side. Ordinarily the inner and outer rails are transposed when the outer one becomes badly flange worn, as already explained, but in some cases the "fins" on the outer side of the inside rail (which would become the gage side of the outer rail if transposed) make the top corner of the rail head so rough that it would be undesirable to place the rail on the outer side of the curve. In such cases the spikes are pulled from the gage side of the outer rail and it is simply reversed in place. Rails which have been in a 4-deg. curve under traffic for several years will, as soon as released from the spikes, spring back as straight as the day they were first laid. To take up rails and swing them end for end, by carrying, requires a gang of at least eight men, but by means of a turning block that is used on the Chicago end of the Wabash R. R., by Section Foreman C. Semberg, the rail is easily turned by one man, taking hold of it with one hand. This device (Fig. 257A) is a 4x6-in. oak block about 15 ins. long, on top of which is placed a cast-iron plate with a hole in the center, and on top of this there is a flanged cast-iron plate with a hub fitting the hole in the bottom plate. Both pieces are parts taken from scrap car iron. When a rail is to be turned, the block is placed in the center of the track opposite the middle of the rail, and two men with tongs lift one end of the rail and set it upon the turning block. One man then takes hold of the rail and walks around with it, swinging the opposite end into the rail seat on the ties, and then two men with tongs lift the other end and set it against the spikes. With this device a crew of only two men can work to advantage.

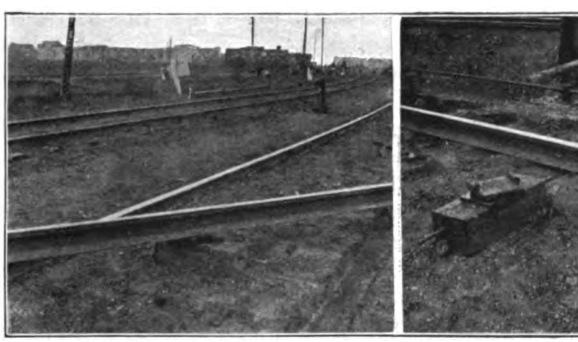


Fig. 257 A.—Rail Turning Block, Wabash R. R.

Renewing Rails.—The detail work of renewing old rails with new ones, sometimes called "changing out" rails, is much the same as when transposing rails on curves. The new rails may be laid on the ties alongside and outside the old rails and the splices be put on and partly or wholly bolted before the old rails are disturbed. Care should be taken to start the joints right with the first new rail. Along straight line new rails may be spliced together in this way to fit closely enough the space occupied by the old rails coming out, for almost any distance; but it is well not to attempt to lay around more than one curve at a time, owing to the variation in length between the old rails and the new rails as they lie parallel to each other before the change. Allowance for the difference in length may be made in the joint openings. For instance, if the new rails are spliced together in a string placed 1 ft. c. to c. of heads from the rails in the track, the difference in length over the same arc of the curve will be about 0.21 inch per degree of curve per 100 ft. of curve, or say ⅕ inch. It would be well, therefore, to distribute this allowance among the joint openings of the new rails, increasing the space with the string lying outside the outer rail of the curve and decreasing it with the string lying outside the inner rail of the curve. The bolts should then be left loose enough to permit the rails to shove through the splices and adjust themselves to the proper opening, upon being thrown to place. If, however, no allowance is made at the joints, the bolts should be turned on tightly, so as to hold the proper spacing against the binding or hauling of the string of rails while it is being thrown to place. This arrangement of course makes the rails hard to move and on long curves the plan will not work; it is better to make allowance in the spacing and leave the splices somewhat loose until the rails are moved to place, after which the rails should be adjusted to an even spacing. If the rails are to be curved, but are not so prepared when unloaded, the most expeditious method is to curve them with lever and sledge, in place, as they lie strung out along the track, carrying two ties along for use, as described in § 24, Chap. III. In considerable practice, however, the plan of unloading the rails in piles, at points along the curve where there is clear space for convenience of curving, is followed. After being curved the rails are distributed with a push car.

As already pointed out, part of the spikes should be pulled and everything possible should be got ready before the time arrives for the change to begin. The spikes pulled beforehand should include such as are driven slantwise, or in any other manner to cause them to pull hard, as, for instance, the spikes in the slots of splice bars. All such spikes, if in the rows of spikes that are being pulled, should be removed, and if necessary to hold the rail, redriven at one side of the slots, where they can be readily drawn the day of the change. In the winter season, when the ties are frozen, spikes start hard. In preparing to renew rails when such a condition prevails some remove part of the spikes and at the same time start the remaining ones and drive them down again, so that they will start easy when the time comes for quick work. If the base of the new rail is wider than that of the old one, all rail-cut ties must be adzed, and this can be done beforehand—several days, if desired—as can also such work as driving down spike stubs, etc. For the work last named a punch is a convenient tool. A machine used on the Pere Marquette R. R. to groove rail-cut ties in preparation for adzing out the rail seat when renewing with a rail of wider base, is described and illustrated in connection with the subject "Laying Tie Plates"—§ 106 of this chapter. Ballast, cinder droppings and other material lying on the ties near the rails or between the ties and higher than the rail base and near it, should be cleared away before the work of renewal, proper, is begun and, in the same connection, there should be a man with a broom to sweep away any dirt that may be kicked into places where it will interfere with the proper bearing of the new rails.

As soon as everything is ready and opportunity offers the spikes are pulled and the string of old rails is cut loose and shoved into the middle of the track, where it may lie indefinitely, if the ballast does not cover the ties; if, however, it must be thrown outside the track before trains may be permitted to pass, it may as well be thrown there in the first place, throwing the old rail over the new. It is best to renew only one side at a time, and if the base of the new rail fits the seat of the old one and there is not such difference in width of heads as to tighten the gage appreciably, trains may be allowed to pass after one side is renewed and made safe. At any rate, it is best not to remove the old rail from both sides until the new rail on one side has been moved into its place and part of the spikes are driven to hold it there, because with both rails removed from the ties at the same time the ties are easily jarred out of place in their beds, particularly where the ballast is not filled in at their ends. In renewing rails on side-track, however, where there is usually more time for the work and where the general excellence of the work is not so important, it is well to combine the work of tie renewing with that of renewing rails, in which case both of the old rails are first thrown from the ties, so as to permit the unsound ties to be upended and thrown out. The new ties may be placed either before or after the new rails are placed—preferably before, if digging must be done outside the track in order to get the ties in. In renewing rails in side-track the best plan is to throw the old rails out in a string and to splice the new rails after they are set into place, one at a time. Nothing can be gained by splicing the rails together in a string on the ends of the ties, as is done in preparation for renewing rails on main track. In driving the spikes for the new rails, all ties down from the rail should be held up with a bar, so that the spike heads may be driven snugly against the rail flange. The occasion for nipping the ties when spiking is greatest where the track is badly out of surface, and for this reason, as well as for the good of the new steel, rough places in the track surface should be attended to before the work of laying new steel begins.

It is better to pull the inside, rather than the outside, spikes when changing or renewing rails, for whenever track gets out of gage it is always a widening, and not a narrowing of the gage that takes place; for this reason the outside spikes should be disturbed as little as possible. But if the base of the rail going in differs in width from that coming out, the new rails cannot be laid to the same gage as the old ones by pulling the inside row of spikes from both rails. In order to lay the new rails to the same gage, the outside spikes must be pulled from one rail and the inside spikes from the other (in curves it should be the *outside* spikes from the *inner rail* of the curve and the *inside* spikes from the *outer rail* of the curve). This rule does not apply, however, to new rails and old rails differing much in width of head, in which case three lines of spikes must be pulled—that is, both outside and inside spikes must necessarily be pulled from one of the rails (in a curve, the inner rail, of course); but one of the four rows of spikes may, and should, remain undisturbed, and obviously it is against this row that the new rail laid first should be spiked. Wherever, as in such cases, the spikes must be pulled from both sides of one of the rails, not more than two-thirds of the spikes should be pulled from either side while the trains are running over the track, and the spikes that remain temporarily should be left in sets of three on the same tie; that is to say, two thirds of the ties will have only one spike remaining (the spike which comes in the row that is not pulled), while at least every third tie should have all four spikes remaining. In exchanging rails of different base width where tie plates are used, the old plates will not answer unless the use of the same with the rail of wider section was anticipated and the plates punched for spike holes accordingly; if such has not been done all four rows of spikes must be pulled. In a case of this kind the aim should be, in setting the new plates, to drive at least one row of spikes in the old holes without plugging, before placing the rail on the plates. In this connection it should be pointed out that tie plates double punched in anticipation of a change of rail section should be so punched and laid that it will not be necessary to change the position of the plates when laying the new rails to gage.

Wherever, for any reason, the spikes cannot be redriven in the old holes, the holes should be plugged. Plugs made to fit the holes snugly should be distributed along the track before the work of renewing begins, and being required in such large quantities it is cheapest and most convenient to get machine-made plugs. If the base of the new rail be not much wider or narrower than that of the old one, the spike may be driven in the same plugged hole, on that side of the plug which will operate to crowd the spike up to the rail, if the base be narrower, and away from the rail, if the base be wider, than the old one. Where both rows of spikes must be pulled from one of the rails in order to lay the new rails to proper gage, it is necessary, of course, while spiking the new rail laid last, to use the gage, as in spiking new track; but in any event the gage should be run along on the new rails as the final spikes are being driven and all points out of gage should be corrected there and then, as previously stated in another connection. Adverting to the work of preparation, it should be stated that the old rails, if in bad alignment, should be lined before the change is made, and it will usually be found necessary to reline the track after the new rails are in, especially if the gage has been corrected in places. After the new rails are laid it is usually necessary to respace the joint ties.

The old rails thrown to the middle of the track may lie there until it is convenient to remove the splices, when, if there is any assortment to be made, the better class of rails should, for convenience of loading, be placed on one side of the track and the poorer class on the other side. If, however, the strings of old rails are thrown upon the shoulders it will cost less to make the assortment when loading the rails on the cars. It is well, however, to inspect and mark the rails in advance of the loading time if an assortment is desired. It is quite frequently the case that the best of the rail removed from main track on the trunk lines is relaid on branch lines, where the traffic is lighter; and rail that is even much worn in main track is usually good for still further use in side-tracks and yards. When old steel is sorted for further service one should be careful to keep rails of the same condition of wear together. Rails removed from curves should not be mixed with those taken from tangents, and rails taken from the outer side of curves should be kept separate from those taken from the inner side. It sometimes occurs that old rail taken from main track is to be relaid in a parallel side-track. In such cases a good deal of labor can be saved by throwing the rails over bodily, in long sections, with lining bars, without removing the splices. In relaying old steel the unworn side of the rail should be used for the gage side; and in laying old curved rails on straight line the curve should be "shaken" out or else the rails on the two sides should lie oppositely bowed, so as to neutralize the tendency of the track to assume a scolloped or serpentine alignment.

The object in splicing together long stretches of rails preparatory to laying them is to do as much work as possible while trains are running, and then to be able to get as much rail as possible into the track during the interval between trains. Where, however, the intervals between trains are very short, or where the track may be abandoned for a large part of a day, as is sometimes done with one of the tracks of a double-track road, between stations or designated crossovers, this practice is not always followed. On roads where the intervals between trains are short, a crew of moderate size, say 12 men, exclusive of flagmen, can make fair headway at rail renewing. Stretches of old rail of such length as can be properly handled during the time available are cut loose and thrown out and the new rails are set in one at a time and spliced afterward; or if the rails are placed along on the ends of the ties and properly spaced they may, with equal facility, be spliced two and two and moved into place with bars. Another plan which is followed to advantage is to put a splice on the end of each rail as it lies on the shoulder, placing the bolts for half the splice but not screwing the nuts on tightly. As the rails are set into the track one by one they are heeled into the splice behind, and it is then necessary to tighten only one bolt to make the splice secure. By this method there need be no delay in fumbling splices during the interval when time is most valuable. When the plan of placing the rails one at a time is followed it pays to renew the ties while changing the rails, but in such event the force should consist of at least 20 men, if the trains run close. If the old ties are cut into deeply by the rails, so that their beds must be deepened in order to get the new ties in, the new ties had better be hauled in after the new rails are laid, but otherwise, or if the ties are in a narrow cut or obstructed at their ends in any manner, it will pay to dress out the old beds and lay the new ties in place before laying the rails, thus saving much digging. If ties are renewed just previous to the time contemplated for renewing the rails, the new ties put in on straight track, if not too close together, should not be spiked until the new rails are laid, thus saving some labor in pulling spikes when the time comes to renew the rails.

Connections.—For closing up temporarily to let a train pass, a switch point (preferably reinforced) is a convenient thing to have on hand; and in order to have it handy when needed it should be carried on a push car just in advance of the old rail that is being thrown out. To make the closure the switch point is heeled against, and spliced to, either the last new rail laid or the last old one, so that the train will trail it, and the split end is spiked down and braced against the mating rail spread outward like the stock rail of a switch. As the latter is not bent sharply it is necessary that the switch point should lie a trifle loose for gage. If both sides of the track are connected in this manner the closure rails should not stand opposite. To lift the outer flange of guttered tires over the spread rail the switch point should stand a little higher than its mate. If the new rail is of larger section than the old one the point rail should preferably be of the new section, so that it may be made to match up against the old rail a little high, without slide plates or shims. To provide for quickly coupling a switch point to an old rail of smaller section, a piece of the old rail may be spliced to an extra switch point carried on the push car; or if an old switch point is to be used for making temporary connection a piece of the new rail may be spliced to a point piece for heeling against the new rail when such becomes necessary. For quickly securing the point piece to the stock rail a special clamp is sometimes used. It is considered that in quitting work for the day it is safer practice to close with a cut rail than with a switch point to be left in the track over night, and on single track such is undoubtedly true; and perhaps so in any case, for if a derailed wheel should trail through such a temporary connection it would very likely tear something out. Nevertheless in closing up for the night on a tangent or on the inside of a curve there are some who will make the connection with a switch point. On the Louisville & Nashville R. R. the use of switch points for making closures is forbidden under any circumstances. In work of this kind the matter of cutting a rail to make closure is not as objectionable as is the practice of cutting rails in general, because the required piece can be cut from one of the old rails.

When switches are encountered during the progress of laying steel, a large crew should not be halted at the switch, but measurements should be taken with a steel tape to start the joints right beyond the turnout and the work continued, leaving a small crew to change the points, frog and lead rails, if such is immediately required, or else to connect the joints one rail length from frog and switch with suitable splices to answer until a more convenient time. As stated in another connection, turnouts should be laid with rails of the same section as those in main track, and such rails should extend at least one length beyond the frog, so as to avoid the use of compromise splices on the switch ties.

In making a permanent connection between rails of different hights and shapes the joint should be a supported one and both a step plate and a step splice should be used—the former to insure an even bearing and the latter to properly join the rails of different section. As step or compromise splices do not, as a rule, fit as closely as ordinary straight splices, it is considered that a supported joint under such conditions will generally give better satisfaction than a suspended one. In Fig. 258 there are shown three methods of joining rails of different section, described by Mr. C. P. Sandberg, an eminent European rail expert. Figure 1 of the views shows a cast steel step splice of angular section joining a 68-lb. with a new 80-lb. rail, as used on the Swedish State line. The weight is about 56 lbs. per pair, and the cost is about $3 per joint. This arrangement has been in use on the Swedish State railways for many years, and is the one used in most approved practice in this country. Figure 2 shows a cast steel "tapered" rail junction designed by Mr. C. W. Kinder, engineer-in-chief of the Imperial Chinese railways, for joining an old 60-lb. with a new 85-lb. rail, the

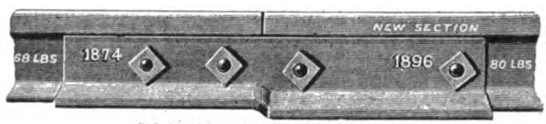


FIG. 1. CAST STEEL STEP FISHPLATE

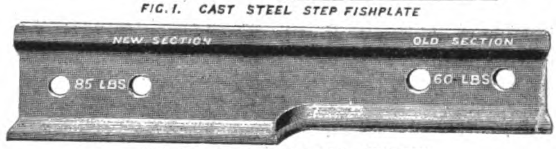


FIG. 2. CAST STEEL RAIL JUNCTION

FIG. 3. FORCED STEEL STEP FISHPLATE

Fig. 258.—Compromise Splicing Arrangements.

ordinary splices for each section being used to make the connection. It is about 27 ins. long, weighs 56 lbs. and costs about the same as the splice shown in Fig. 1. Figure 3 of the views shows an 86-lb. bullhead rail joined with a 100-lb. T-rail by plain rolled step fish plates weighing only 34 lbs. per pair. These are made from a bar rolled to the larger section and planed, or sometimes by forging in a die, under a steam hammer or press. On general principles the steel rail junction shown in Fig. 2 is not a good style of connection, being a piece of rail too short for use in main track. A rolled steel rail of standard length tapered down to the smaller section at one end would undoubtedly give better satisfaction. On the Southern Pacific road tapered junction rails made from ordinary rolled steel rails are in standard service. The piece of rail is 7½ ft. long and the reduction in section is made gradually, in a length of 15 ins., near one end of the piece, by heating and forging. In reducing the width of the rail head the gage side is kept straight and the taper is made on the outside. On each side of the web of the rail, covering the tapered portion, there is riveted a reinforcing strap 2 ft. 10 ins. long. An "offset" splice is one having a lateral jog in the bars, for connecting rails having different widths of head, it being necessary, of course, to hold the gage side of the heads in line, as well as to hold the tops of the same even. In making connection with an offset splice care should be taken to have no lip on the gage side of the head. If the heads do not match right for this they may be brought into line by applying a thin strip of oak wood of proper thickness to the outside of the web of the rail of smaller section and to the inside of the web of the rail of larger section and then bolting on the splice bars over the wood strips (See also §27 and §212).

Rail Renewing Crews.—An important question which arises in connection with rail renewing is whether the work should be done by the section crews or by an extra gang. To do the work to advantage a crew of at least 12 or 15 men, besides the foreman, is required, and if undertaken by the section crews this means either the hiring of extra men temporarily or the combining of the forces of adjoining sections. The former plan is not always practicable just at the time the men are wanted, and the latter plan cannot very well be carried out during the summer season without delaying or disarranging the regular work. The most available time to do the work with the section crews is during the late fall or winter, when other work is not pressing, but if the ground is frozen there is no opportunity to take up simultaneously, or to follow with, certain other work of track improvement, such as tie renewing, respacing joint ties or lining. And finally, when the work is done by the section crews it is likely to progress in patches, at several points on a division at the same time, and consequently with greater tendency to disturb the train service, for a train may be flagged several times in getting over the division. Undoubtedly the best arrangement is to work an extra gang of good size, beginning at one end of the division or of the section of track on which the rails are to be renewed, and working continuously. By this plan the train service is interrupted at only one point, and in striving to apply uniform methods to all the work the roadmaster has only one foreman to deal with. Where the work proceeds continuously there is a better opportunity to keep the old material picked up behind the work and do what is considered a "clean job" than is the case where the work moves at slower pace here and there and the whole division is strewn with old material at intervals.

By whatever plan the new rails are laid they should be distributed continuously. Where the work has been done by the section crews it has frequently happened that the new steel would be distributed first to those sections where the foremen were ready to take up the work, and then something would happen to cut short the supply of new material until another year. In this way stretches of poor rail would become isolated between sections laid with new rails and have to be retained in service another year or perhaps longer. When finally these sections of poor rail came to be renewed there existed a difference of a year's service on adjoining sections and it may also have chanced that the rails supplied later were of better quality than the first, so that in course of years the condition of rail wear on comparatively short subdivisions of the road, taken at random, was somewhat variable and of an alternating character. The result is that when it comes to renewing rails the second time in such cases, it is necessary to remove some of the old rail prematurely in order to lay the new rail continuously. If the new rail is of heavier section than the old one or of different pattern there are certain advantages to be had in laying it continuously, such as a uniform stiffness in the track structure, which is readily observed in the riding of the cars; and the opportunity to reduce the patterns for switch points, frogs, tie plates etc. to a single standard in each case.

On roads where Sunday work is the rule, laying new steel is usually done on that day, when there are fewer trains to bother. The preliminary work is carried out on the day, or during the few days, previous by the section crews, aided by the work-train crew and floating gangs, perhaps, and on the day the change is made a large force is employed. It is seldom imperative to use this day for the work, however, for a large force may be employed on any day or with any of the various methods in practice. On the Boston & Albany R. R. it has been the practice for the train department to give up a section of one of the two tracks and operate the trains on single track past the stretch where rail renewing is under way. Rail-cut ties are adzed and some other work is done before the actual operation of laying begins. Out of a crew of 200 men about 40 are put at pulling spikes, this gang being divided into three lines—one for each row of spikes pulled. One set of men in each line use straight claw bars with a heel of small radius, starting the spike up an inch or more above the rail flange, while another set are provided with goose-neck bars or with bars having a heel of long radius, for pulling the spike the remainder of the way out. Six or eight men with pinch bars throw out the old rails in a string and 25 to 30 men complete the work of adzing the ties, sweeping and otherwise preparing the seat for the rail. The "setting in" gangs are two in number, of 16 men each, who handle the rails with tongs. In case the rails are spliced in pairs beforehand the number of men in these gangs is doubled. The remainder of the crew work as strappers, spikers and nippers.

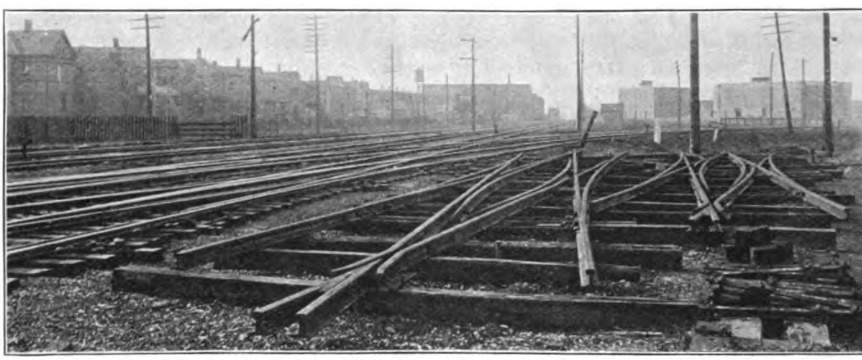


Fig. 258 A.—Crossings and Double Slip Switches Assembled in Preparation for Renewal, Chicago & Western Indiana R. R.

With a view to present data to be used as a basis of estimation, the following records of carefully planned work at rail renewing may be of service. On a road of crooked alignment, curves of 1 to 5 deg. being almost continuous, over which was moved a traffic of 83 trains daily, crowded pretty close together in the morning and late afternoon, a gang of 47 men renewed the rails on an average of 1 mile of track per day. The new rail was of heavier pattern than the old, requiring a readjustment of $\frac{1}{2}$ in. in the gage. The men were distributed for the work in the following manner: 2 flagmen, 6 pulling spikes, 3 throwing out old rail, 5 adzing ties, 8 carrying rails with tongs, 1 applying expansion shims, 1 holding rail up to spikes with bar, 6 spikers, 1 pulling spikes for new splices, 1 adzing ties for new splices, 12 strappers (6-bolt angle bars), 1 spiking new joint ties. This record was submitted to the Roadmasters' Association of America by Mr. J. B. Dickson.

In another instance, on a single-track road carrying rather light traffic, a record of 3.2 miles of track relaid with 75-lb. rails replacing 61-lb. rails, was made in 9 hours with a crew of 98 men. The rails were full bolted with 38-in. 6-hole angle bars and full spiked on curves, of which there were four. On straight line only alternate ties were spiked, except that spikes were driven in all slotted angle bars which came right to catch a tie, which was the case with about two thirds of the joints. This is a record of rush work, and is not supposed to be repeated as an average result.

In another instance where the work was carefully planned, but not rushed, 12,000 ft. of rail (one side of the track) was relaid with 85-lb. 60-ft. rails in 6½ hours including an intermission of ½ hour for dinner, 12 trains passing while the work was in progress. As a matter of preparation, the adzing of the rail-cut ties had been done 2 months previously, and, on the day before, alternate spikes were pulled from one side of the rail, it being necessary to pull only one line of spikes to make the renewal. In making the change the old rail was thrown out without unbolting the splices and the new rails were set in one at a time. Every other tie was spiked exclusive of as many joint ties as came right for the splices, which were 6-bolt angle bars. Two to four bolts were placed in each splice. The rails were spiked ahead of the strappers, and in this way their ends were brought even for splicing. The crew consisted of 41 men distributed along the track in the following order: 1 man pushing a hand car carrying a switch point, bolts and nut locks, who distributed bolts and nut locks—7 men pulling spikes—4 men moving out old rail—14 men setting in new rails with tongs —1 man placing expansion shims—2 men holding new rail up to the spikes—5 men spiking alternate ties—1 man taking out shims and putting on splice bars—5 men tightening bolts—1 flagman, who, by the way, had tools to keep himself busy correcting errors and supplying deficiencies. By dividing the work in the foregoing manner each man was assigned particular duty and did nothing else.

Renewing Crossings and Switches.—In renewing the rails and frogs at crossings, crossovers or in a network of switches on parallel tracks, it is to some extent the practice to couple up the various pieces of lead rails, frogs, switches, movable-point frogs etc. in the order in which they will lie in the track, laying them on skids of old rails or old switch ties placed on the right of way opposite the point where they will go into the track when the change is made. In making the change the old devices are taken up and the new parts are shoved laterally into position, bodily, with bars, then coupled up at the ends and spiked to place. In this way changes can be quickly made, and at points where busy traffic must be taken care of the plan is a means of saving considerable time. In renewing crossings it is also the practice on a number of roads to handle the frogs, already connected, with a derrick car. On the Chicago & Western Indiana R. R. the crossing frogs on two tracks and one rail of a third parallel track, at a long-angle crossing, solidly bolted together in one piece, have been lifted out with a derrick car, and as many frogs for the new crossings, all bolted up for service, set into place by the same means. An account of some of the work of renewing crossings and switches on this road will serve to bring out the details.

The particular piece of work selected for description was the renewal of crossings and slip switches where a double-track line makes junction with four tracks of the main line of the Chicago & Western Indiana R. R. This junction consists of a double leader crossing three of the four Chicago & Western Indiana tracks, making a double slip switch connection with two of them. The work of renewal consisted in replacing the crossings and slip switches on the two westerly tracks of the C. & W. I. R. R. The four tracks of the road at this point are used by a number of tenant companies, and a heavy freight traffic is handled by the C. & W. I. R. R. itself, so that to do the work satisfactorily, it was found to be necessary to abandon the two tracks mentioned while the work of renewal was under way. For doing this work two Sundays were selected, one crossing and double slip switch being renewed on each day. Preparatory to the work of renewal, the crossing frogs, movable point frogs and slip switches were laid out and assembled on switch ties, each opposite its final place in the track, as shown in Fig. 258A. On each day of renewal the tracks were abandoned early in the day, the interlocking connections were broken, the old rails, frogs, switch points, interlocking parts,.etc., and the unserviceable ties were taken up and carried out of the way, and the new crossing and double slip switch was thrown in bodily with lining bars. To hold the parts to proper gage while being thrown the rails were spiked to two long planks near each end, and at the middle of the crossing the rails were solidly blocked apart, making the whole piece, weighing something like 7½ tons, rigid enough to be thrown bodily.

The work of renewal on the first day included the replacing of a crossing and double slip besides a single plain crossing. After the old material had been taken up and carried away the decayed ties were replaced with new ones and three skid rails were put into position and oiled for launching the new work into place. Figure 258B is a view showing the launching operation in progress. In order to move the slip endwise and get it into exact position it was jacked up and skid rails were laid longitudinally underneath four points of the crossing diamond, namely, under

Fig. 258 B.—Moving a Crossing and Double Slip Switch Bodily into Place, Chicago & Western Indiana R. R.

the end frogs and under the point-rail heel castings. After moving the new work into place it was spliced to the old track rails and spiked down, and then surfaced up on new rock ballast. In the meantime an interlocking crew was busy at making the necessary connections for restoring operation from the tower. All connections of this kind necessary to put the tracks into regular service were completed by evening of the day of change. The facing-point locks were not put on until the following day, and to insure safety of operation during the night a watchman was stationed at the crossing and the switches, when thrown for the high-speed movements, were spiked. The working force numbered about 65 men, including three extra gangs of trackmen and an interlocking crew of ten men.

Changing Gage.—Leaving roads of 4 ft. 9 ins. gage out of consideration the mileage of roads of other than standard gage is comparatively very small, in this country; but there are a considerable number of narrow-gage roads and branch lines of short length, 3 ft. being the gage of nearly all. The building of narrow-gage roads in this country has practically ceased and those that remain are fast becoming standardized, either as a means of increasing the capacity or to discontinue the inconvenience and costly work of transferring freight at junction points with standard-gage roads. The work of changing track from narrow to standard gage is in many respects similar to that just considered and may properly receive attention here.

Preparatory to changing the gage of track it is usually necessary to widen fills and cuts, modify and strengthen bridges and trestles for the heavier rolling stock, and renew at least a portion of the ties with longer ones for the increased gage, 6 ft. being the common length of tie for track of 3-ft. gage. Such preparation is accomplished most economically if carried out gradually, during several years, beginning as soon as there is any certainty that the change will be made, and working with the contemplated end in view, as opportunity is seen. In following such a plan much can be done in the course of ordinary repairs, thus avoiding expense which might accrue from waste of materials discarded should the substitution of the same be attempted within a short time before the final change. In renewing the ties of the narrow-gage track with longer ones either of two methods may be followed: the tie may be laid to project equally beyond both rails, in which case both rails must be moved when widening the gage; or the tie may be laid with reference to one of the rails only, projecting beyond it the proper distance for standard-gage track, in which case only one of the rails need be moved when the gage is changed. The latter method obviously shifts the center line of the track, and on bridges could not be permitted without moving the bridge, as it would produce an unequal distribution of the load upon the trusses of the bridge or upon the posts of a trestle bent; and if the track center was to remain the same on the bridge but not elsewhere, a new alignment would have to be made each way from the bridge for some distance. The method also requires that the widening of the roadbed for the longer ties be made on one side of the track, which might not always be feasible without moving the track; as along a side-hill cutting in rock, for instance, where it might be cheaper to move the track than to widen the cut. As a general proposition there is probably nothing to be gained by this method and the usual practice is to widen the gage by moving both rails. Otherwise the bearing for the changed rail is partly upon a strip of newly formed roadbed or newly tamped ballast, which might make it difficult to maintain the track in level and surface for awhile, besides giving trouble from center binding. If both rails are to be changed it is not necessary that all of the ties of the narrow-gage track should be replaced by those for standard gage, except perhaps on sharp curves. On straight line, two thirds of the short ties, and on ordinary curves half of the short ties, if sound enough for further service, may remain. The supporting power of the short tie is, of course, inferior to that of the longer one, and projecting a shorter distance outside of the rail, its spike-holding efficiency is less, but if the long ties are somewhat uniformly distributed no serious trouble will arise from matters of this kind.

The preparation made immediately before the final change is begun usually consists in pulling part of the spikes, preparing new seats for the rails and in driving part way down a row or line of spikes for one or both the rails in the new position. On straight line two thirds of the spikes may be pulled from each side of both rails before traffic is discontinued; on light curves half the spikes might be pulled from both sides of the inner rail and from the inside of the outer rail; on heavy curves, say half the spikes from the inside of the inner rail. Ties with warped upper face, ties cut into deeply by the rail and "bellied" ties with the ends curving upward outside the rails should be adzed down, to give the rail an even bearing when it is moved over. A gage for testing the uniformity of this work may consist of a piece of board or narrow wooden strip notched (say ½ inch) to fit over the narrow-gage rails, with depending blocks or lugs of proper depth to mark the position of the rail base. In standardizing the gage of 110 miles of 3-ft. track on the Flint & Pere Marquette Ry., in 1898-99, the seats for the rails in their new position were cut by a traveling tie spotting machine described under the section (§ 106) on "Laying Tie Plates," further along in this chapter. A record of the work which there appears presents an interesting comparison with figures given in connection with the present subject. When widening the gage of the Burlington & Western and the Burlington & Northwestern roads, from Burlington to Oskaloosa and Washington, Ia. (123.1 miles), on June 29, 1902, the rail seats had been prepared during the two weeks previous by a portable sawing machine similar to the one above referred to, working over 12 to 15 miles of track per day.

The best gage for driving a row of spikes for the new rail is a short piece of hard-wood board of proper width, the board being used edgewise against the web of the rail and the spike driven against its outer edge. To secure neat gage it is perhaps best to drive only one row of spikes for a guide line, the second rail being spiked to the gage after the first rail has been secured, as in spiking new track. The spikes in the row or rows driven as a guide line should be taken from those pulled from the ties, so as to minimize the demand for new spikes.

All the work of preparation being completed, traffic is abandoned for a time and a large force is set to work pulling spikes, moving over the rails and spiking them to the new gage and changing the switches and turnout leads. On tangent the track can be made safe enough temporarily for the passage of trains by driving every third spike, but each tie that is spiked should receive all the spikes (four) for both rails. At first only such work as may be necessary to allow the trains to pass need be done, but as soon as possible thereafter the rails should be fully spiked and lined, the old spike holes plugged, all old material picked up, rubbish cleared away, etc. If the steel is to be renewed at the time of changing the gage the final work can be much simplified, for the new rails may be spiked to the proper gage outside the old rails, using spikes pulled from the old rails, without interfering with the traffic. The traffic need then be delayed only while the breaks are being closed at the switches. If, therefore, a change of gage is in contemplation at a time when the rails are poor or beginning to show the worse for wear, it may pay to either delay the rail renewing or to hasten it, as the case may be, so that both jobs may be done at the same time.

It may help to a better understanding of the conditions involved to state briefly the facts concerning some actual cases of changing gage. One instance of this kind was the widening of 57 miles of track on the Columbia & Puget Sound R. R. and branches (Pacific Coast Company), from a 3-ft. gage to standard gage, on Nov. 14 and 15, 1897. The idea of making the road standard gage had been in the minds of the management for some years, and timely preparation was made. The preliminary work of standardizing began in June, 1897. Several Howe truss spans were rebuilt and the bridges strengthened, wherever necessary, for the increased loads. Twenty thousand 8-ft. ties were put into the track which, with those already in, replaced practically all the narrow-gage ties on the line; and 11 miles of 56-lb. rail was laid in place of 30-lb. rail remaining. On account of a demand at the company's mines for the 30-lb. rail at this time, the 56-lb. rail had to be laid to 3-ft. gage, so that the light rail could be released. This stage of the preliminary work was practically complete on Nov. 1. A gang of 75 men was then put to work on the track pulling all the spikes which could be spared with safety, and in preparing lead rails for use with standard-gage switches. The new ties had been laid symmetrically in the 3-ft. track, so that it was necessary to move both rails. To facilitate this work some of the spikes pulled were driven in line by gage, so that they would be in the right place on the outside of one of the rails when put to standard gage. The gage used consisted of a board 8x12½ ins., shod on each end with sheet iron. One end was placed against the web of the rail and the spike driven half way into the tie at the other end of the gage, thus forming a line against which one rail could be moved out when the track was spread. This work was finished on Nov. 13, and on the same day the necessary switch rods and a supply of new spikes, to take the place of broken or bent spikes, were distributed. By midnight all the narrow-gage cars and engines were unloaded and stored, all traffic having been run to the full capacity during the day.

It was estimated that an average of five men to each mile could spread the track and lay the necessary switches in two days, one day being Sunday, when little traffic would ordinarily be handled. This number, therefore, was sent out on Saturday and divided into four gangs, and each gang given a certain district and certain switches to complete. Each gang of men was divided into three parts: The first pulled spikes, the next threw the rails out with lining bars and the third gaged and spiked, the number of men in each squad being so regulated that they kept well together. After the rails were spread each gang went back over its own district and full-spiked the rails, put on curve braces and changed what switches had been omitted during the first two days. In the matter of tools the men had 150 claw bars, 100 lining bars, 150 spike mauls and 50 track gages. The change was begun at 7 a. m. Sunday, and the track was spread, quarter-spiked and the switches put in by Monday night, when the first through train passed over the road. By forcing matters a little in train service, before and after the change, there was very little loss in the volume of traffic, and outside of delays for a few days in running trains at reduced speed over a quarter-spiked track, the change was not materially felt.

The best record made was by a gang of 36 men, who spread both rails on 12 miles of track, about one third of which was on curves, and put in three switches, in 24 hours. The track around the curves was all changed by this gang without cutting a rail. The rail was freed for a mile at a time, the splices loosened and a curve to the left worked into a curve to the right, thus compensating the expansion and contraction necessary to move the rail in and out with respect to the curves. That is to say, the stretches of rail moved were so chosen that what was gained in length on one curve was compensated by the necessary decrease in length on another curve turning in an opposite direction. On sinuous location with short distances between the curves, the practicability of the scheme is apparent, and by loosening the splices no difficulty should be experienced in carrying from one curve to the other whatever length the rail might run over or fall short by being moved over to a curve of slightly shorter or longer radius. It might here be suggested that the same method of procedure could be employed to advantage in the work of transposing rails from the outer to the inner side of a series of curves, if the curves are not too far apart. Where the curves are some distance apart the most rapid method would probably be to take care of the lengthening of the outside rail temporarily by opening the joints, and provide in advance for the shortening of the inside rail by cutting a piece of proper length to connect in when the change is made.

Another instance of widening gage, of particular interest because of the unusual conditions existing and of the novel method of doing the work, was the standardizing of the Columbia & Western Ry., from Trail to Rossland, British Columbia, in 1899 (This road has since become a part of the Canadian Pacific Ry. system). The peculiar features of the line are its steep grades and sharp curves, the road rising 2300 ft. in its length of 13.6 miles. The grade on all tangents was 4 per cent and the curves were compensated .04 per cent per degree. The maximum curves were 25-deg., of which there were 38, the aggregate length of which was approximately 3 miles; and there were two switch-backs. The track, of 3-ft gage, was laid with 6-ft. ties and 28-lb. steel rails. The cuts were 10 ft. wide and embankments 9 ft. in width. In addition to widening the gage the road was to a large extent reconstructed, the maximum curvature being reduced to 20 deg., cuts widened to 16 ft. and embankments to 14 ft. Four out of eleven trestles were filled and the others were strengthened. The grading was done during the fall of 1898. The work was done under the immediate direction of Mr. F. P. Gutelius, superintendent of the Rossland branch of the Canadian Pacific Ry. The plan of the work was different from usual practice, in that not only were new 60-lb. rails laid in connection with the widening of the gage, but new 8-ft. ties were also laid at the same time, thus entirely rebuilding the track upon a widened roadbed. The change was carried out gradually by tearing up the old track and laying an entirely new track, at the rate of about ½ mile per day, meanwhile carrying the narrow-gage rolling stock upon one of the rails of the new standard-gage line and a third rail laid temporarily to serve as the other side of the narrow-gage track. The narrow-gage switches were temporarily retained in service, so that all that remained to be done, as soon as the new track was laid, was to go back and lay the switches of the standard-gage track. The conditions being such that traffic could be accommodated by a night schedule for a few weeks, the usual custom of abandoning traffic for one or more days during the period of transition from one gage to the other was avoided.

Some of the details of this work may be useful information. As the old track had been laid but three years there had been no tie renewals and consequently no opportunity to gradually replace the short ties with ones of standard length in the course of ordinary repairs. The material for the new track was delivered by narrow-gage work trains, just ahead of the workmen, in the day time. The system of renewing out of face was adopted, thus allowing joint ties to be properly placed and rails to be full spiked as the new track was being laid. By this method a gang of 40 men would remove 2500 ft. of old track and replace it with standard track each day, the best record made for any one day being 3800 ft. The third rail put down for narrow-gage operation was only half spiked. Each evening the new track laid that day was connected to the undisturbed narrow-gage track, over which the narrow-gage trains were run during the night. The operation of narrow-gage trains on one 28-lb. rail and one 60-lb rail was not attended with any difficulty or accident. Rails were cut for standard-gage switches for all spurs, passing sidings and switch-backs, although temporary narrow-gage switches were laid as the work progressed, except in case of the Smelter Junction yard, where the tracks were arranged for use of both gages. Here a combination switch was used, and a movable-point frog operated by bell cranks attached to the regular switch stand was used (where the lead rail of the standard-gage turnout crossed the narrow-gage rail) instead of a double-point rigid frog. By June 14 the entire standard-gage track had been laid except for the substitution of standard for narrow-gage switches, of which there were fourteen. These switches were changed on June 15 by 100 men, in six gangs. The work of changing the switches was started at 7 o'clock, after all the narrow-gage equipment had been unloaded and taken to Smelter Junction, where it was stored. At 13 o'clock the first standard-gage passenger train started and by 15 o'clock it had passed over the road.

Referring to examples of more extensive changes, but not so much in detail, in the period between May 22 and June 2, 1886, the gage of more than 12,000 miles of track on various roads in the South was changed without interrupting the trains for more than a single day in any case. This change was from broad (5-ft.) to standard and 4-ft. 9-in. gage, and included 1806 miles of Louisville & Nashville main line and side-tracks, which was accomplished in a single day, May 30. The force employed on this occasion averaged 4 men to each mile of main line and siding and 5 men to each mile in the terminal yards, the total number of workmen employed being 8763. Preparation for the change at the crossings was made by cutting out at the middle of each side the requisite length of rail and then holding this piece in place by splice bars until the day of the change, when the cut pieces were removed and the sides of the crossings moved in to the newly adopted gage.

On July 9, 1885, the Mobile & Ohio R. R. changed the gage of its entire track of more than 500 miles in less than 12 hours, interfering with the movement of only one passenger train and a few freight trains. In this instance the cost was $27.99 per mile. The time required to do the preparatory work, such as adzing ties even with the rail seat and setting gage spikes, averaged 53 days' labor per section of 8 miles, and for pulling spikes just previous to the change, 20 days more. Only one rail was changed—the west rail—the east rail remaining undisturbed. Gage spikes for the new position of the west rail were driven to within 1½ ins. of the top of the tie. On the day before the change every other spike was drawn from the west rail and straightened and three new spikes were distributed to each rail. On the day of the change every other spike was driven on the outside of the changed rail and the gage spikes previously set on the inside were driven down. Switch rods adjustable at the center, by cutting in halves and overlapping (Engraving *H*, Fig. 145), had been gradually put on the switches before the change of gage commenced, and preparation had also been made for moving all switch stands located on the west side of the track. Precaution had been taken to provide each section with standard gage hand and push cars. The organization of each section crew on the day of the change was as follows: 4 men pulling inside spikes, 1 man driving down stubs of spikes from which the heads were broken in pulling, 3 men throwing out rail, 12 spikers working in pairs, 2 extra spikers, 1 nipper, 3 men shoving cars and doing miscellaneous work; or 26 men in all, besides the foreman. One day's supply of cooked provisions for the entire force on each section, water, spikes and extra tools were carried on the push cars, of which there were two—one car of 5 ft. gage pushed ahead of the work and a standard-gage hand car following after. At alternate meeting points between the sections two gangs began together and worked away from each other until meeting the next gang. The work commenced at 4 a. m. and was finished at about 4 p. m. or earlier. The pay of each laborer on this day was $1.50 and rations. Enough side-track was changed at each station to accommodate at least one freight train. The best record made was 5 miles of track changed in 5½ hours. To put the track into final shape, after the change, required about 50 days' labor per section of 8 miles, exclusive of superintendence.

96. Broken and Bent Rails.—Rails are most liable to break during very cold weather. One reason for this is that the ground may heave irregularly in places and make the support for the rail inelastic and uneven; another reason is that loss of heat has a tendency to make the metal brittle. There are those who dispute the latter statement on the ground that steel shows the same tensile strength at low temperatures that it does at ordinary atmospheric temperatures, but most trackmen know how difficult it is sometimes to break a rail during a hot day by notching and dropping it, and how much easier a rail can be broken in the same way during cold weather. Again, at even a moderate heat, far below red heat, steel rails may be bent quite sharply without breaking. A variation between 150° F. above zero and 40° F. below zero, must show some difference in the brittleness of the rail, if not in its tensile strength. Some experiments on steel rails by Mr. C. P. Sandberg, made in Sweden in 1888, showed that out of 21 specimens put to the drop test under a 1-ton ball, ten broke at —22° F. and only one at +90° F. The specimens were taken in pairs from the same piece of rail, one of each pair being tested at the lower temperature and the other at the higher temperature stated. In another instance reported by the same authority, specimens of rails requiring a drop of 39 ft. to break them at 84° were broken with the same weight falling only 11 ft. when the thermometer stood at 10°. Mr. P. H. Dudley has pointed out that cold weather has the effect of decreasing the ductility of the

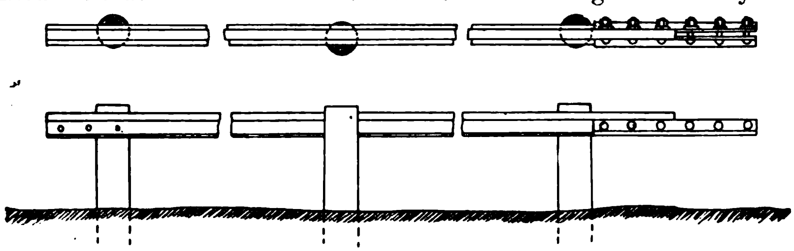


Fig. 259.—Rail Rest.

metal of the rails, but slightly increasing its tensile strength, elastic limit and modulus of elasticity. He also directs attention to heavy tensile stresses which may exist in the rails at low atmospheric temperatures, due to the tendency of the metal to contraction when the ends of the rails refuse to render in the splice bars. Such stresses might be sufficient, when combined with stresses from the moving loads, to start fracture at some flaw or gag mark. Straight pulling tests in the testing machine on two pieces of 95-lb. rail spliced with 20-in. angle bars showed that the metal could be stressed more than 12,000 lbs. per sq. in. before the rail would slip in the splice bars.

The danger from broken rails depends upon circumstances and the character of the break. If the break occurs over a tie support on straight line, or on the inside rail of a curve, and is a square break, derailment is not liable to occur; nevertheless there is danger; but if the break is between tie supports, or occurs on the outside rail of a curve, there is much danger of derailment. If the break occurs between tie supports when the ground is frozen deeply there is danger that a piece of rail may be broken out, which, if it occurs, will result almost surely in derailment. It is likely that in many cases of derailment from broken rails, the rail is broken by the very train to which the derailment happens. Rails break perhaps most frequently within the splice bars; but if the broken-off piece is not longer than 6 ins. or so and the break is square, so that the splice holds it, there is no danger. The tendency for rails to break most frequently near the end is undoubtedly due to the heavier stresses there arising from the greater deflection at the joint and to the pounding effect of the loads on low joints. It is also suggested by students of the metallurgical side of the matter that the greater tendency to break near the end than at intermediate points may in some measure be due to the metal in that portion of the rail having come from material too near the end of the ingot, in rolling, in which case seamy or brittle metal would be expected.

Whenever a dangerous broken rail is found, trains should be stopped and passed over it slowly until after it is temporarily repaired or another rail has been put in its place. The quickest way to make safe at a broken rail is to drill two holes and bolt on a splice. If the break is found in the night or the section crew, for any reason, is hard to find, or no spare rail is near, this is by all means the best thing to do; because all the tools and materials can be carried by one man, the work can be done by one man in a few minutes, and the rail is thereby made practically as safe as before the break. If the fracture is a "clean break"—that is, squarely across the rail or nearly so—and not too near a joint, the spliced pieces, fully bolted, may remain permanently, in lieu of laying another rail in their place. If a rail should be broken in more than one place, however, another rail should be laid in its stead as soon as possible. It is well to always measure, in some way, the length of the rail broken before going for a new one; if it is on a curve it may be one of the short rails. When a broken rail is taken out of the track the rail laid in its place should be one of the same pattern or section, and as nearly as may be in the same condition of wear. A broken joint splice leaves the track in a condition equivalent to that of a broken rail, although it does not usually create the same degree of excitement among the track men. In case a frog is broken beyond repair in place, and there is no spare frog on hand, a piece of rail may be laid in place of the frog. When such is done the switch should be spiked and the roadmaster and the train dispatcher promptly notified to that effect.

Rail Rests—Spare rails, sometimes called "emergency" rails, should be kept on hand at convenient points about a mile apart—say at every mile post. They are needed to replace broken rails occasionally and are handy to draw from when rails are needed at a wreck. These rails, if left lying on the shoulder half sunken into or half covered by the ballast, will, when wanted in a hurry some cold night, be found "tied fast" or perhaps covered with snow. Spare rails should be placed at least 18 ins. from the ground, on some kind of support located convenient to the track and in a clear space. Rail rests are made in a variety of forms, almost any of which are good enough for the purpose. A very common arrangement is to set two or three posts on a line parallel with the track and notch the tops to hold a rail in the inverted position (head down). In some instances spare rail posts set in this way are notched deep enough to hold a second rail laid on top of the other, base to base, or drift bolts are set into the sides of the posts to serve as pegs for supporting a second or third rail. Very frequently the middle post is set slightly out of line with the two end ones and the notching is done as in Fig. 259, to permit the rail to rest on its base. Rail rests for 60-ft. rails on the Pittsburg, Cincinnati, Chicago & St. Louis Ry. consist of four posts 10 ins. square set 16 ft. apart and notched according to the arrangement in Fig. 259, half the width of the post and two rails deep. Another arrangement, where it is desired to keep more than one rail at a place, is to set old bridge ties in a leaning position and notch out a series of seats or steps to hold the rails, on the inclined upper sides of the ties. Similarly, heavy planks are sometimes set in a vertical position and stepped out on the edge, to hold two or three rails.

The style of rail rest shown in Fig. 260 is used on the Southern California Ry. It consists simply of posts and caps made from old switch or bridge ties set up on a piece of leveled ground and neatly embellished with a paving of whitewashed stones around each post. The capacity for spare rails is larger than is usually the case with a rest consisting of vertical or leaning posts and the rails are just as conveniently got at when wanted. The standard "rail rack" of the Southern Pacific Co. is a two-bent arrangement of this kind, the posts or bents being 16 ft. apart. When level ground is available it stands 2 ft. 3 ins. high, above the ground, and 20 ft. clear of the track rail. When set on the side of an embankment it is placed lower than the bottoms of the ties and 6 ft. from the track rail. To prevent mischievous boys from shoving spare rails over embankments, without going to some exertion, the rails may be put through holes in the posts, as in Fig. 261. As examples of more permanent construction, the Lake Shore & Michigan Southern Ry. uses 6-ft. pieces of old rails for posts, set with the web facing the track, with old fish plates bolted to each side of the web and bent outward and upward to serve as brackets to hold the rails. The standard rail rest of the New York Central & Hudson River R. R. (Fig. 262) consists of two posts of old 60 or 65-lb. rails 7½ ft. long, set 4½ ft. in the ground and 18 ft. apart, with iron cross arms bolted to the bases of

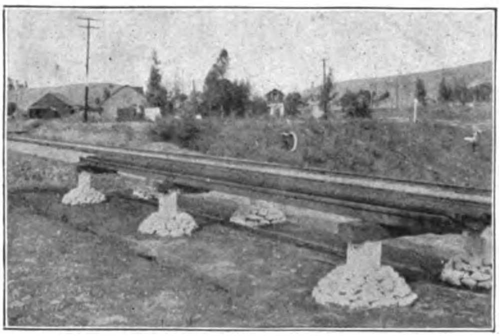
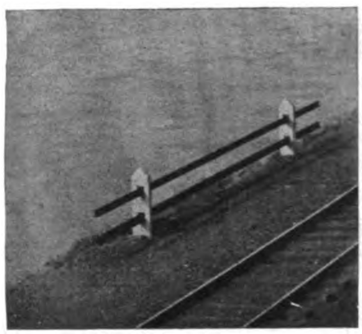



Fig. 260.—Rail Rests—Fig. 261.

the rails to serve as rests for the spare rails. The posts are painted black and around the foot of each there is a cobble paving. These rests are located at mile posts, two miles apart. For single-track lines one cross arm and two spare rails are standard; for double-track lines, two cross arms and four spare rails; and for four-track lines and large yards, three cross arms and six spare rails. Where curves are numerous it is well to have at the mile post at the middle of the section or at the mile post most convenient to the curves, a spare short rail of the length habitually used on the inside of the curves. Each spare rail should have a pair of splices bolted to it, and a few spare spikes should be cached somewhere near the rail rest.

The rules of the maintenance of way department of the Southern Pacific Co. require that in addition to the spare rails kept on hand for use on each section (six rails for each main-line section and three rails for each branch-line section), known as "section stock," each roadmaster's district shall be supplied with at least 1000 ft. of rail of fair quality, suitable for construction of temporary tracks around wrecks, washouts or slides, piled where it may be readily loaded on cars. All other rail which may be on hand is reported as "repair stock," and no section is allowed to have such material piled in more than three different places.

Bent Rails. Rails sometimes get bent and have to be straightened or else taken out of the track. A side kink in a rail may be taken out by prying with three bars against the rail—one bar being placed at or near the kink, as though to straighten it, and the other two placed against the rail a few feet on either side, so as to pry in a direction opposed to the single bar. Pry hard with the bars and at the same time strike the rail at the kink a few blows, against the side of the head and the edge of the flange, with a sledge-hammer; if it is not bent too much it can in this way usually be straightened. If this method fails, use the jim-crow at the bend and pry against the rail with a bar or two while the jim-crow is being screwed up. A roller rail bender can also be used to staighten side-kinked rails in the track. In one instance reported to the New England Roadmasters' Association, where the rails on ½ mile of track had been kinked inward through some defect in the running of a locomotive, the kinks were removed by working a roller rail bender along on the rail. Where moving rails at stub switches are bent by being thrown before the car has passed entirely over them, take one rail out, and turn it end for end, so that its spring counteracts the spring of the rail opposite. Where there is not sufficient ballast to hold it, the first spiked tie under the switch rails, nearest the head-block, will be moved over with the rails, especially if the switch rails are short, and the rail at this point will not move all the way back when the switch is thrown back to main line, thus leaving a kink in the rail at that point. To remedy a matter of this kind, throw the rails to line when the switch is set for main track and drive a stake firmly into the ground hard against the end of the first spiked tie, so that it cannot be moved when the switch is thrown .

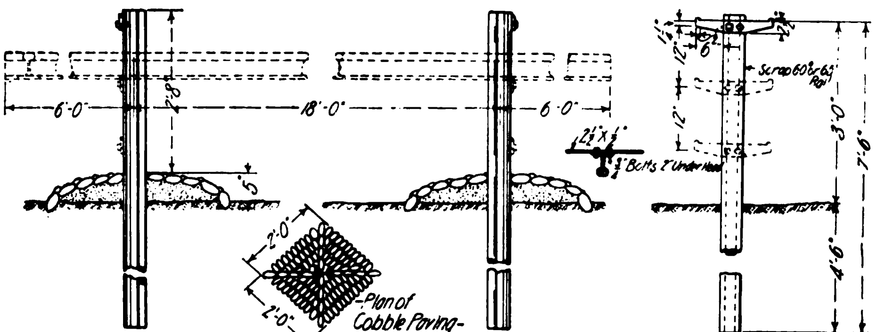


Fig. 262.—Standard Rail Rest. N. Y. C. & H. R. R. R.

On roads running through timber, rails are bent occasionally by falling trees. A rail badly surface bent cannot be straightened in the track, but should be taken out and another rail put in its place. One way to straighten such bent rails is to take them to a turnout, build a fire and heat them to a cherry red, not getting them too hot, because it is difficult with a wood fire to heat the rail very hot without heating it for several feet each side of the kink. In the angle back of the frog place two short pieces of rail across the two near rails of main track and side-track, one underneath and the other on top. The former piece will serve as a hold, and the latter as a rest, for the rail to be straightened, and the latter piece should be adjusted to come under the bend in the rail. When the rail is sufficiently heated pry downward with it between these two short pieces until the rail is straightened. About six men will be required to handle the rail, and tongs may be used to handle the hot part of the rail, if necessary. If the men know how to act together and fully understand what moves are to be made, the rail can be straightened very nicely. This method is best for straightening a kink at or near the quarter in a whole rail or long piece of rail. If the kink is near the end of the rail it can be straightened by heating the rail, laying it across a track rail for a support, placing the kink directly over the support, and striking down on the end of the rail with a heavy sledge. If the kink is at or near the middle of the rail, place the rail over the fire, supporting it at the kink by a piece of rail crosswise, the long end of the rail hanging over unsupported and the other end secured under a track rail or in some other way. When the rail becomes sufficiently heated it will bend down from the weight of the overhanging end, or at any rate by pushing down on it a little. Ordinary men who will take a little pains and use good judgment may satisfactorily straighten some pretty badly bent rails by such methods. Some will do to go back into main line and the others can be used in side-tracks. The following information regarding some work of straightening rails in a different way was furnished me by Mr. C. C. Dunn, of the Atlantic Coast Line:

"Several years ago I had considerable experience with straightening bent rails on another road. In this instance there were a great many surface-kinked rails in the track and we found that the best and cheapest way to do the work was to handle the rails with a floating gang. This gang was provided with a portable forge and a rail bender of the same pattern that is used for straightening alignment kinks. Of course a rail bender could be made for surface kinks that would work better. It does not require a very heavy forge for this work. If I remember rightly, we used a Buffalo No. 3 forge which we procured from a bridge gang. With this forge we could concentrate the heat on the exact point desired. We started with about 12 good rails to substitute for the bent rails taken from the track, and in a short time we very much improved the rails in 30 miles of track."

97. Regaging.—If rails are spiked to gage when the track is laid, the gage on tangents will seldom vary, if proper attention is given to it in tie renewals. The gage of curves, however, will spread when the ties get old, and it needs readjusting now and then. The wear of the outer rail of curves widens the gage by the amount of wear to the side of the rail head. On some roads the gage is adjusted occasionally for this widening, by moving one of the rails in a distance corresponding to the side wear, but such is not general practice, since the increase of gage by the wear is everywhere the same; and then when it comes to transposing the outer and inner rails the original gage is restored, unless the rails have spread. In regaging track which has been improperly gaged when built, pull both outside and inside spikes and plug the holes with wooden plugs which fit snugly, driving them to the bottom of the hole left by the spike. Holes should not be plugged with sand. If the change in gage is only slight the spikes may be driven in the plugged holes at one side of the plug; but if it is much, each spike should be driven near the other edge of the tie face from its old hole. It is always proper to drive a spike in an old hole where it can be done by plugging, because every additional spike hole weakens a tie at the place where the greatest pressure and bending moment come. But when a spike cannot be driven in the old hole beside a plug and reach the rail flange when the rail is in the right position, it should then be driven as far from the old hole as possible, in order to be in sound fiber. Back-spiking—that is, driving a spike at the back of a spike already driven, in order to crowd it against the rail flange—should not be practiced; a plug will do the work just as well, if the spike be pulled and the plug be driven tightly enough. If the rail has spread, having been in good gage before, simply pull the outside spikes and then plug and redrive. If the spikes are badly cut in the neck, pull them out and throw them into the scrap pile; and it may sometimes occur that by driving new spikes in the old holes, without plugging, the rail can be brought back to gage. If this can be done it is better than the practice of bending the head of the cut spike against the flange, or breaking off the head of the spike and driving another spike in a new place, to weaken the tie. In using new spikes the outside of the rail should be given the preference; that is, the new spikes should be driven on the outside of the rail, as far as they go, and the same rule applies to the best of the old spikes when such are redriven. The best time to do regaging on improperly gaged track is in the winter, when section work is slack.

It may here be explained that "spreading rails," as popularly understood, is a good deal of a bugbear. On fairly sound ties rails, if kept spiked, will not suddenly spread to dangerous extent. The spreading of rails and lateral displacement of spikes is seldom if ever caused by overwhelming pressure from the wheel flanges acting at one time. Such displacement is a gradual process, caused by lateral flexure of the rails, which increases in amplitude and intensity, of course, after the spreading of the spikes has once started, such action being most liable to begin where the track is out of line. On sharp curves without rail braces or tie plates the outer rail is quite liable to spread, but proper inspection and attention are sufficient safeguards. Many accidents charged to "spreading rails" may be traced to derailment from some other cause. Of course rails are likely to be spread after cars have been derailed.

Tie Plugs.—As already intimated, wooden spikes or tie plugs are much needed on old track, and it pays to have them made by machinery. Each section should have a supply on hand; and if they are not furnished from headquarters the crew, or part of it, should spend time enough at the tool house during wet weather to keep a good quantity ahead all the while. Straight-grained, sound oak ties, old brake beams, etc., may be cut up into blocks and the plugs split out with beetle and hand-ax. They should be kept in a barrel so that they will not be kicked around and wasted, and a few should always be carried on the hand car with the iron spikes; otherwise it will often be found necessary for one of the crew to putter around splitting slivers off fence boards or the ends of the ties, to make tie plugs. Unless the holes left in ties by pulling spikes are plugged, rain water will enter them and penetrate the surrounding fiber, the result of which is to hasten the decay of the tie under the rail seat. Tie plugs should be made of tough wood, which will stand hard driving, so that they may be made to entirely fill the hole without breaking. Pine and cedar are not suitable for this purpose, being too soft or brittle and inclined to break off before reaching the bottom of the hole, with the result that the plug will go partly down with the spike when it is driven, leaving the spike without backing at the neck. White oak and ash give satisfactory results, but second growth elm is recognized as the best material, being tough and presenting a roughened surface to the spike when the latter is driven through it. The Goldie tie plug, which is designed to fill all the hole left by pulling a spike, has a wedge point somewhat more blunt than that of a spike, with a body of the same size as the main part of the spike but with an enlarged top end to fill the oblong hole in the face of the tie made by the backward bending of the spike as the claw bar rolls back on its heel.

An interesting application of tie plugs is made on the Paris, Lyons & Mediterranean, the Northern, the Eastern and other roads in France, to increase the holding power of screw spikes and dog spikes in soft wood ties and in old ties in which decay has started around the spikes. A wooden screw of hornbeam or other hard wood, 2.08 ins. in diam. at the top and 1.38 ins. at the bottom, having a thread with a pitch of 0.59 in. and a depth of 0.197 in., is screwed into the tie in position for each spike and then sawed off flush with the tie face. There is an iron band around the screw plug to prevent splitting, and a hole in the center for the spike. The procedure with old ties is to bore out the old spike holes and tap them for the screw plugs. With new ties all of the holes for each tie are bored at one operation, by machinery, before creosoting. A series of experiments with a dynamometer showed that the increase in the holding power with these wooden plugs was 29 per cent for Baltic pine and 39 per cent for Landes pine ties, while with old ties 8 years in the track, the percentage was greater, being 80 for pine, 33 for beech, and 62 for oak. It is also found that the ties resist decay longer, as moisture does not penetrate the wood and the hard screw plugs prevent the tie plates from working into the timber. The device was invented by Mr. Albert Collet.

98. Righting Canted Rails on Curves.—The canting or tilting outward of the inside rail of curves is caused either by the elevation of the outside rail, being too much for the slow trains; or by unsound ties. The former cause is explained at length in § 44, Chap. V. Where the elevation is found to be too much it should be reduced by raising the inside rail; but neither this nor replacing part of the old ties with sound

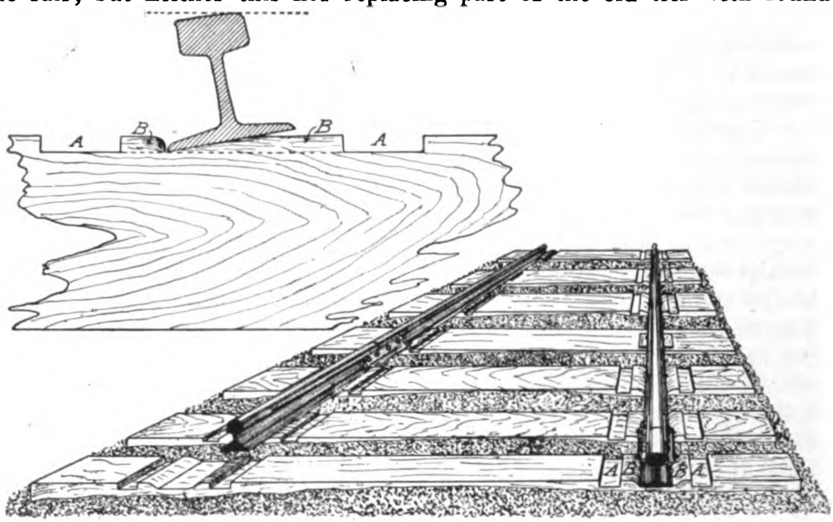


Fig. 263.—Work of Tie Spotting Machine, Pere Marquette R. R.

ones will bring the rail back to its proper position. This can be accomplished only by adzing the rail seat to a proper bearing. The way to go about it is to pull all the spikes from the rail, both outside and inside, and drive all stubs of spikes ½ or ¾ in. into the tie. Also clean away all ballast which may be on the tie face near the rail base, or near the rail base between the ties. Raise the rail about an inch and block it there and adz each tie to a bearing for the rail, parallel with the plane of the tie face, although if the ties are old it might be made to cant the least bit inward. Then let the rail back to its place and drive the spikes in the old holes. By taking not more than a rail or two at a time the work can be done without much hindrance from trains, and, being the inside rail of the curve the track can be made temporarily safe to let trains pass by tacking down hastily a few of the spikes. As the work progresses the rail will tip back to place and to proper gage.

In the work of righting tilted rails on the Pere Marquette R. R. a traveling tie spotting machine has been used to prepare the ties in a way to facilitate adzing out the rail seat. This work of preparation consists in cutting a groove into the tie face, each side of the rail and even with the base of the same, as illustrated in Fig. 263. In the upper view there is a sketch of a tilted rail. The grooves cut by the machine are lettered "*A*," and two shoulders (*B*) remain between the rail and the grooves. To prepare the seat for the rail in its righted position it is only necessary to chip away the shoulders *B*, which readily split off to the bottom line of the grooves. The construction of this machine and its method of operation are described and illustrated (Figs. 279-281) in connection with "Laying Tie Plates," the subject of § 106, of this chapter.

A sure cure for canting rails is the use of tie plates. This device cannot be too highly recommended for service under rails that show a marked tendency in this direction, especially after they have given trouble and been straightened up. Where tie plates are applied in a case of this kind they serve to fill up to some extent the depressions or notches in the tie face caused by adzing down the rail seats; and prevention of recurrence of the trouble is more especially desirable at this stage in the life of the tie, because repetition of the process of cutting into the tie by rail and adz will ruin many a tie that should see longer service.

99. Cutting Rails.—Rails are usually cut by first notching around with a track chisel and then breaking at the notch. The piece of rail to be taken off and used should be measured accurately, allowance being made for expansion, and it is usually notched squarely all the way around. As measurements are usually made along the rail head, the first cutting is made across this portion; and pains should be taken to have it started squarely across, for upon the manner in which this first cut is started depends largely the success of carrying the cut squarely the rest of the way around the rail. It is well to mark a line for this first cut, with a rule and pencil, because it is somewhat difficult to sight squarely across a rail to the blunt edge of a track chisel. After the notch or groove has been cut across the head, stand over the rail and sight squarely past the ends of this groove to the edges of the rail flange, and mark these edges with the chisel. By these marks the notch can then be extended all the way around. In notching, one should cut into the corner or fillet between head and web as much as possible. In cutting across the base the notches on the two sides of the flange, near the edge of the flange, should so nearly meet that the rail shows signs of cracking or fracture there. In short, notch all the way around the section as deeply as the chisel will cut conveniently; and chisels which have become much blunted should not be used. By continually pounding on a blunt chisel the steel is toughened at the cut and is liable to break on one side of the cut instead of in it. The rail while being notched should rest squarely across a track rail, or squarely across a short piece of rail placed on a sound tie which is solidly bedded. It is much easier to notch squarely around a rail if the support is perpendicular to, or square with, the rail, than otherwise. The cutting should be done directly over the support. This done, the rail is ready for breaking. A rail notched squarely all the way around is pretty sure to break off right; that is, if it is broken in the right manner.

About the easiest way to break a notched rail is to do it with the jim-crow, providing this device can be used. If the rail to be broken in two is a short piece the jim-crow is by all odds the best means to employ, for, unless the piece of rail has considerable weight it cannot be easily broken by striking it or by throwing it. If the jim-crow is not used, and the piece to be taken off is less than 3 ft. long, lay the rail on its side, with the notch directly over another rail for a support, and break the piece off by striking the end of the rail with a heavy hammer or sledge, or by dropping upon it a piece of rail as heavy as a man can lift over his head. To break off pieces 3 to 8 ft. long from a long piece or whole rail, raise the rail and let it drop across another rail or piece of rail, falling on its side with the notch directly over the support. In breaking off a considerable piece the rail need be raised only hip high, but to break off a short piece the rail should be lifted as high as one's head. If all the men fully understand what is to be done and step aside at the word, no one need ever get hurt; and if the notch is dropped directly over the support the rail will not be kinked. In taking off pieces longer than 8 ft. there is too much spring to break the rail by throwing. In such cases the rail to be broken should be laid on its side, parallel to a track rail, 6 to 10 ins. therefrom, having the head turned toward the track rail and supported on pieces of rail or blocks 3 or 4 ins. high placed near the ends, or at least far enough away from the notch each way to allow considerable spring in the rail. Then pry down over the rail, near the notch, with a bar, taking hold under the head of the track rail, at the same time holding a track chisel in the notch on the side of the head and striking it a heavy blow. A piece as short as 2½ or 3 ins. may be broken from the end of a rail by notching it and striking with a sledge; but it may be done with one blow, or it may take a half hour. For cutting off such short pieces the hack saw or other rail saw should be used. When it is found especially difficult to break a rail in hot weather, turn it on its side, make a little mud dam on the web, on each side of the notch, and cool the rail by pouring in cold water and allowing it to stand a few moments.

One way to break off a short end (pieces 10 ins. to 3 ft. long) from a rail is to notch it on the sides and around the base, rest it workwise on an end bearing, have the men stand upon it, hold the chisel in the notch on top of the rail flange and strike it with the hammer. In breaking rails it is not necessary to notch them across the top of the head, and some do not notch the sides of the head. Where rails are broken by dropping them on side across an anvil some make it a practice to notch only one side and across the bottom of the base. The rail is then lifted and dropped with the cut side up.

A rail may be cut or broken in two without removing it from the track, by notching it conveniently deep on the sides and top with a chisel and breaking it with the jim-crow. A good break is best assured in a case of this kind by first cutting the head clear through with a hack saw. Before applying the jim-crow pull all the spikes on one side of the cut, so that that end may be free to swing when the rail is bent. After a rail has been notched and broken there will be found a burr on the broken end, which should be trimmed off with a hand cold-chisel, so as to give a smooth bearing for the splice bars. Tools for cutting rails, such as chisels and saws, are considered in § 125, Chap. IX.

100. Expansion in Rails.—Failure to allow the proper amount of joint space when laying rails is generally the cause of considerable repair work afterward. Where too much space is allowed rails will, in extremely cold weather, pull apart at the joints, breaking either the bolts or the splices, and leave a dangerous opening, particularly if such pulling apart occurs on the outer rail of a curve. But it is more frequently the case that too little space is allowed, so that the evil effects thereof are felt mainly in hot weather. While the coefficient of expansion for steel undoubtedly holds good in all cases, yet it almost seems that no reliance can be placed upon it in summer time with rails in the vicinity of a stub switch. Here is where the bad effects of too little space for expansion are first seen. The rails will expand so tightly that the switch cannot be thrown during the middle of the day without the aid of a hammer to drive the rails over. Of course, the only remedy is to take out a piece of rail, and this is done by cutting about 3 ins. from the end of some rail back of the moving rail. Leave an opening of about ½ in. at the headshoe and take up the rest of the 3 ins. by opening out joints farther back. If the joints in the direction of the frog also are tight, the same thing must be done with the rails on that side of the headblock, or else the headblock will continually be shoved toward the moving rails. In doing this the piece of rail should be taken out somewhere beyond the frog or guard rail and the full number of holes should be drilled for the bolts of the splice. The short pieces of rail taken off should be buried in the ballast under the joint, so that they may be had to put back when cold weather comes, if needed. If the steel is pretty tight in the joints the rails will have to be shortened more than once during the summer. In driving rails apart a track chisel should be used which is rather sharp and thinly drawn out, as a blunt chisel is not good for starting the rails to move and it will also raise a burr at the ends of the rails.

The tightening of the rails on the headblock at stub switches is not, however, the only inconvenience and trouble caused by the expanding of close-jointed steel. During hot days the rails will kink into a snaky alignment, and they cannot be thrown in line until after cooling down; and then, not to stay there. On curves, frequently, and sometimes on straight line, tight rails will expand and shoot sidewise out of line several inches within a rail's length or so. This phenomenon is commonly known among trackmen as a "sun kink," and has often been the cause of a wreck. It is almost sure to occur with close-jointed rails where the ties are not well filled in between. It usually takes some time to get such kinked rails back into line, as the only remedy is to take out a piece of rail. But rather than hold a train very long at such a point it is well to throw the track out *with* the kink, temporarily, for a rail or two each side, making a longer curve, or, on tangent, a double reverse curve, over which the train may be allowed to pass slowly. When laying a shorter rail in such a place allowance should be made for proper expansion at the joints for some distance in each direction. A sun kink is sometimes started while the track is being raised for tamping or while throwing the track into line. When the rails are expanded and crowded together tightly a slight disturbance will sometimes cause the track to buckle in the manner above indicated, particularly on curves, or where there is only a small amount of filling between the ties. Filling against the ends of the ties makes track secure against expanding steel, and hence track should always be filled in that way if the quality of the ballast is such that proper drainage will not be interfered with.

101. Stretching Steel—Sometimes the proper amount of space for expansion is allowed but not evenly distributed, there being tight joints between successive rails for a distance, so that the rails will kink when the weather gets hot; and then a number of joints at which the openings are wider than necessary. If this state of things exists only in short stretches of track in a place, it may be remedied by manipulating the splice bolts to take advantage of the expansion or contraction in the rails. The most favorable opportunity to do this is when there is a considerable change in temperature between night and day, or between the middle of the day and evening or morning. The way to go about the work in summer is to start during the cool of the day and loosen the bolts at the open joints. When it gets hot the expansion of the rails will run into and toward the loosened splices, the bolts of which should then be tightened, at the same time loosening the bolts at the tight joints, so as to allow the latter to pull apart when it gets cooler. The operation should be repeated two or three times, or until the space for expansion becomes evenly distributed among all the joints. After slackening the bolts on a splice the bars should be struck a side blow with a hammer, to loosen them, and to give the rails free movement, the slot spikes should be drawn from the splices. If the work is undertaken in winter the bolts should be tightened on the open joints and loosened on the tight joints. During the night the tight joints will be pulled open. The next morning the bolts should be tightened at the joints which have pulled apart and loosened at the others. By keeping up this practice for a few times the joint openings may be readjusted to even spaces.

Where the necessary amount of space for expansion has not been allowed a piece of rail must be taken out and the space thus obtained evenly distributed among all the joints. To start with, a piece as long as the distance between the first two bolt holes may be cut from the end of a rail, the rail thus shortened to be laid in place of a whole one when the time comes to begin the work of pulling open the joints. This arrangement will permit the use of at least one of the original bolt holes in the shortened rail. After ascertaining how many joints must be opened out in order to take up the space to be gained by laying the shortened rail, the bolts should be removed from one side of the joint in each of the splices, so that the rails may be pulled apart. Thus all the splices remain on the rails, with half the bolts at each joint still in place, so that the running of trains is not endangered. Only such spikes are pulled as are found driven in the slots of the splice bars or such as will be in the way of the splice when the rail

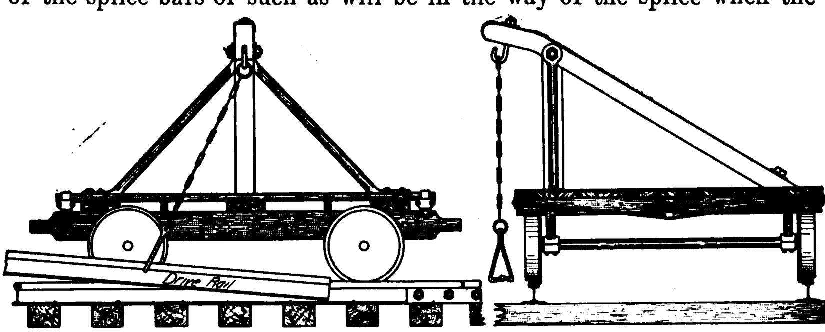


Fig. 264.—Rail-Driver Truck, Yazoo & Mississippi Valley R. R.

is moved. The shortened rail is then laid in the place of a whole one taken out, and the close-jointed rails are driven toward the opening, one at a time, and properly spaced at the joints. The work can be done rapidly, and a space longer than 6 or 7 ins. never exists between any of the rails while they are being moved. Should a train approach while there is a wide gap still undistributed, a rail or two may be quickly driven to divide the space among two or three joints. Where too much space has been allowed at the joints the latter may be closed to the proper interval by driving the rails along in the manner just described, putting in a short piece of rail or "dutchman" as often as the gap opened up behind amounts to a few inches, but not exceeding 6 ins. in length. The joints at each end of such a short piece of rail should be closed up tight and should be supported by a tie directly underneath, respacing a few ties in the vicinity, if necessary, to bring one under the dutchman. The splice should then be full bolted. The length of the dutchman is usually determined with a view to have some bolt hole in the shifted rail come right for service.

Another occasion for stretching steel arises from the creeping of rails on hilly roads, where the rails pull apart on the summits, opening up the joints, and drive together, closing the joints, in the hollows. Particularly is this true of single-track roads, where the running of trains both ways on the same track drives the rails into each hollow from both directions. In such cases it is necessary to drive the rails back from the hollows toward the summits, making a redistribution of the expansion allowance, which, if properly calculated when the track was laid, can be done without cutting rails or laying dutchmen. In such places, however, the work proceeds from the summits toward the hollows, and on a long hill the gap opened up in setting back the rails may become so long before reaching the "bunched" rails in the hollow that temporary use of a short piece of rail must sometimes be made in order to close up and let a train pass. Careful attention should be given to the proper spacing of rails in side-tracks, as well as in main track. It has frequently happened that close-jointed rails in side-tracks have expanded, pushing the frog out of its proper alignment for main track or shoving the headshoes against the moving rails at stub switches. Where such trouble occurs it is necessary to stretch the rails in the siding.

The method of driving rails when stretching steel, known as the "butting back" process, is to strike the end of the rail or the end of the attached splice bar with a piece of rail 8 or 10 ft. long. The piece of rail is handled in various ways. Where it is butted against the end of the rail that is being driven, the joint is first opened up about an inch wide with a track chisel and hammer. The striking end of the butting piece is slid along on top of the rail behind and the other end is held about hip high, so as to cause the striking end to drop into the opened joint and strike against the end of the rail to be driven. If the rail is to be moved by striking against the end of the splice bar the butting piece is either swung as a battering ram or slid forward on the ties.

The work of handling the driving rail, either when held in the hands of the men or swung with tongs, is severe physical exertion, not only in the act of striking, but also in carrying it from joint to joint as the work proceeds. On the Yazoo & Mississippi Valley R. R. a push car has been rigged up to carry the striking rail in such work. The division of this road extending from Vicksburg, Miss., to Wilson, La., 113 miles in length, is quite hilly and creeping rails are bothersome, the trackmen finding it necessary in years past to drive the rails on about half the length of the division annually. Formerly this work was done in the ordinary way, with a squad of eight or ten men handling the rail serving as the driver, and so fatiguing was the labor of carrying it from place to place that a new crew had to be put on about every six hours. The arrangement of the push car above referred to is shown in Fig. 264. In the middle of the car, at one side, there is a vertical post secured to the car decking and by side brace rods, while extending across the car there is a beam inclined upwards and framed over the top of the post, the overhanging end being provided with a hook bolt, from which hangs a chain and grapple a few inches clear of the side of the car. In closing up an interval between two rails the truck, with the drive rail hanging at the side, is run to a proper position behind the joint splice to be driven, and the driver is then swung and guided to strike the splice. The number of men required to handle the driver in this way is only three, but two men can do it quite handily. Aside from the saving of labor in lifting and carrying the rail the truck is also utilized for carrying the tools needed in the work, and short pieces of rail or switch points used in closing up openings when it is desired to let a train pass. As the framework is light the truck is easily set off the track after the driver rail has been released from the grapple.

102. Adjusting Bolts.—The importance of keeping track bolts properly tightened is not always recognized. It seems to never occur to some foremen that loose bolts may be largely responsible for most of the low joints on their sections. No matter how much tamping is done, track cannot be maintained in good surface easily if the bolts are allowed to get loose and stay in that condition very long at a time. The strength of splice bars is effective only when the bolts hold them tightly in position; in fact, so far as efficiency of the splice is considered, leaving safety out of the question, the nuts might as well be entirely off the bolts as to be at all loose. And then, if track bolts are allowed to remain loose for any considerable length of time the threads of the bolts become so much worn or battered that they are no longer fit for service. Where day track-walkers are employed they should be kept busy at tightening or adjusting bolts when not actually engaged in patrolling the track. If this work is not done by track-walkers, one day each month should be devoted to it by the section crew. In winter time, when work is not pressing, much attention might be given to tightening bolts, and in wet weather, in other seasons, the time can be put in at such work to good advantage. The splices should all be kept fully bolted with good bolts and the bolts should be tightened evenly. The effect of one bolt much tighter than the rest is to loosen the two adjacent ones.

Although it may not generally be thought so, bolts in splices may be got too tight, so that evil effects may result from overtightening as well as from loose bolts. Bolts may be turned on so tightly that the rails will kink or the track buckle before expansion can take place at the joints. In view of this fact some trackmen take the precaution, when raising track on curves during very hot days, to slacken the bolts on a few splices before lifting the rail, in case the appearance of things seems to require it. Experiments conducted by Mr. P. H. Dudley on testing machines showed that a force of 46 tons was required to start the ends of 80-lb. rails spliced with 40-in. six-bolt angle bars, and a force of 23 tons to slip one end of the same rails spliced with 22-in. four-bolt angle bars. To slip 95-lb. rails in 20-in. four-bolt angle bars required a force of 30 tons, and after the angle bars had been "sledged in" and tightened again the force required to slip the rail in the splice was 58 tons. These records prove that track bolts turned on hard resist rail expansion and contraction with great force. To cite one instance where due recognition is taken of this fact, it is the practice on the French Eastern Ry. to lubricate the splice bars, in order to facilitate the shifting of the rail ends under temperature changes. It should be taken into consideration that splice bars, when tightly adjusted, are wedged in between the head and flange of the rail very securely, and that all there is required is to keep them to a snug fit. In order to do this it is not necessary to screw on the bolts until they are at the point of snapping in two. A splice may be adjusted very tightly and still allow the rails to expand through it. Each rail should be so held by the splices at its ends that it may expand and contract in its place; but where the bolts on some splices are too tight several rails may expand as one rail, and either kink themselves into a snaky alignment or shove rails less tightly spliced; hence the importance of adjusting bolts to a uniform tightness on all the splices. The reason why some joints pull farther apart than others is because the bolts on the splices are not so tightly adjusted as on the others. To remedy a situation of this kind the bolts may be slackened on the open joints in the morning, and then during the heat of the day, when the rails have closed in, all should be adjusted to an even tension. Where good spring nut locks are used it is not necessary to adjust the bolts as tightly as otherwise. When tightening a loose bolt on a splice one should inspect carefully to see whether any of the others have been slackened, and if such is the case each should be readjusted to take its proper share of the work.

Foremen should make a thorough study of this matter and learn for themselves, from observation and experiment, the proper adjustment for track bolts, and then see to it that all the men do the work right and uniformly alike. A man can pull on an ordinary 18-in. wrench with enough force to break a ⅞-in. track bolt. The practice of lengthening out wrench handles with a piece of pipe, 2 ft. or so long, is an indication of either ignorance or laziness, or both. A wrench with so long a handle cannot be manipulated as dextrously as one with a handle of ordinary length. That part of the operation of tightening a nut which requires the most time is in screwing it to take up slack and to bring the bolt to a snug bearing; the number of pulls at the wrench requiring the laying out of strength are comparatively few. A section crew trained to know when track bolts are properly tightened, have learned an important matter in track maintenance.

While bolts are being adjusted, cracked splice bars should be replaced with sound ones. While a cracked splice may answer for holding the ends of the rails in line it is of no more account in supporting the joint than a broken one. The broken or cracked splices should not be thrown into the scrap pile. The pieces make good temporary rail braces, which come handy in shimming, or they serve quite well for two-bolt splices for joints in unimportant spur tracks or sidings—that is, if the bolt holes come right for the holes in the ends of the rails.

103. Creeping Rails.—There are two longitudinal movements, or tendencies to movement, in rails: one, a molecular movement of expansion or contraction in the metal, the other a progressive shifting of the rails bodily, commonly known as "creeping" or "running." The former is caused by change of temperature and its effects, however severe, are local—that is, the damage resulting from expansion or contraction of rails will always be found in the near vicinity of improperly spaced joints, and movement takes place in the direction of least resistance. With steam roads this movement is practically irresistible. The tendency to movement by creeping is caused by the running of trains, and is always in one direction for the same direction of the moving train. Where this movement takes place it usually extends over comparatively long stretches of track. The tendency is sometimes held in check and usually may, to some extent, at least, be prevented. There are some peculiar things related of creeping steel, some of which would apparently defy satisfactory explanation on existing theories for the cause. It is now pretty generally conceded, however, that the principal cause is the wave motion in the rail set up by moving trains. There is usually a slight upward and then downward movement of the rail and ties just preceding a moving locomotive or train, owing to the flexibility of the rail, but the whole ground also springs for quite a depth underneath the track and for some distance each side, so that there results a wave motion in the rail of much greater amplitude than at first appears. Those who are interested in the subject of track depression may find some account of extensive experiments in this direction in § 181, Chap. XI.

Starting with the fact that there is a wave motion in the rail, it may be explained that if the rail was continuous this wave would be propagated along it simply as an undulating motion and there would be no onward movement in the rail any more than there could be in the ground. But by laying the rail in sections of 30 ft., or other length, the propagation of the undulating motion is more or less arrested at every joint (completely, where the splice is loose) and each section of the rail is permitted to sprawl ahead. Hence the running or creeping of rails takes place successively by sections, one section at a time; or, at most, by a few sections acting together as one; and this is why steel may creep and not close the joints, as many have undoubtedly observed. So, while the ground and the ties undulate continuously, and return again to the position in space occupied before the train arrived, the rail undulates intermittently by sections and does not return unless provision be made to compel it to do so; that is, unless each rail is made to hold fast to the ties and ground it will remain shoved ahead by a very small amount at each passage of a train.

The reason the rail is shoved ahead when it loses the undulating motion is this: When a heavy load rolls along the track the ground and the rails with it give downward. This giving downward with the ground is a displacement, and earth is moved outward in all directions and compressed; but after the load passes, the earth, by virtue of the elastic force due to its compression, moves back to its former position, the old level of the roadbed is restored, and its motion has been simply undulating or oscillating. Now, if the rail was continuous, as the load rolled forward it would stretch out the rail behind and crowd it together in front, compressing the particles slightly, thus setting up behind an elastic force of tension, and in front, an elastic force of compression, in the rail, both of which would act to restore the disturbed portion to its former place after the load had passed; then the rail would undulate with the ground. But with a rail made up of spliced sections the undulations cannot be fully propagated unless the splices hold the joints securely enough to resist the stresses from the undulations as firmly as the solid part of the rail; otherwise the rail will shove through the splice ahead, into the open joint, and pull through the splice behind, and there will be no elastic force to return it to its former position relatively to the ground. Hence the ground and the ties, which are embedded in the ground, undulate backward after the load has passed, but the rail remains shoved ahead relatively to them, unless provision be made to carry it back. Although such forward movement can take place only by almost imperceptible stages, it takes place, nevertheless, wherever the rail is not so held to the ties as to be carried back with the undulations in the ground and ties; and the space at the joint is just what permits this creeping, for it could not take place except by sections. If it was possible to tighten splices so as to hold against creeping they would be too tight to allow the rails to expand easily, and much evil would result. The two movements do not take place in the same way; for creeping occurs only under the trains, while with rise in temperature every section of rail along the whole line expands at the same time.

Three important facts should be noted in connection with creeping rails: the creeping is most rapid during hot weather, it is greater on double than on single track, and it runs with the trains. In hot weather the rails must expand; and some splices may be bolted tightly enough to cause the expanding rail to flex or bend. If there is but little filling between the ties or the spikes be not driven snugly up to the rail flange the rail may kink laterally and throw itself out of line. But if there is filling at the tie ends, or the spikes have not been kept driven down to the flange of the rail, or if the ties are sawed four-square, so as to be easily lifted through the ballast, or if there are low joints, the rail may spring upwards or camber more readily than it can be forced through the splices at either end. Many have doubtless noticed this; and how in some hot days the cambering of the rails at the centers gave the appearance of low joints, for the time being. Now a locomotive running over these cambered rails will depress them and such depression must drive the two ends of the rail further apart, of course, the friction of the splices not being sufficient to hold the rails back. But the load rolling on from one end will cause the rail to slip through the splice in the forward direction, as carpet is ruffled when the foot is shoved over it; because no matter how loose the splice behind, the weight of the rolling load tends to hold that end of the rail firmly and to drive ahead the other end.

But there is another reason why rails should be expected to creep faster in hot than in cool weather. When the rails are heated up the tendency to expand sets up considerable compressive stress in the metal before properly bolted splices will permit the rail to give at the joints. When there is no train running this compressive stress or force might be considered as producing an equal effect toward expansion in both directions and all the rails might be considered as being frequently stressed up to the point of forcing the splices. As the train advances, however, the wave in the rail preceding it should increase the stress in the rail just ahead of the train, and the jarring effect of the advancing load on the molecular structure of the metal would be expected to cause the rail to suddenly expand and slip through the splice. As has just been shown, this expansion will be in the forward direction, or away from the point where the rail is held down firmly under the train. Now when the rail is in tensile stress, as in cool weather, any disturbing cause, such as the jar of a train running over the track, will affect the creep of the rail in the same manner; that is, the rail will be forced to suddenly contract and pull away from the point where it is held firmly under the train; but the tendency will be to creep less, because the wave in the rail running ahead of the train will operate to relieve the rail, just ahead of the train, of some of its stress. It seems likely that the jarring of the rail by moving trains, while the rail is in a state of stress, may have no small influence in the creeping of the rail at all times, for the rail is in stress, either of compression or tension, at any time when the temperature is rising or falling—that is, if the splice bolts are kept properly tightened. Most trackmen have probably seen a rail on a very warm day suddenly expand to fill the joint opening upon loosening the bolts at a tightly spliced joint, the sudden increase in length being accompanied usually by a loud report, showing that the rail had been subjected to heavy stress. In very cold weather rails will contract with equal suddenness upon being freed from the gripe of a tightly bolted splice. However much, change of temperature, as a primal cause, may have to do with rail creeping, it is certain that except for the running of trains the rails would expand and contract in place; and as every effect due to the running of trains is to cause the rails to move forward, the tendency of rails to creep is always forward, or in the direction of the movement of the train which causes it, and never backward. Another reason why rails should creep more rapidly in summer than in winter is that when the ground is frozen it is less yielding and there should be less wave motion in the track.

On double-track roads the tendency for each track to creep is in one direction only. On single track, if there be no predominating influences favoring one direction, the tendency to creep in one direction is balanced by that from the other, and movement, if at all, is slight and not nearly so much as on double track. It has been observed, however, that on single track, with traffic one way much heavier than the other, the rails creep with the heavier traffic; also that on single track the rails creep habitually down grade, owing no doubt to the faster speeds in that direction and, on heavy grades, in some degree perhaps to the continuous application of brakes and the back action of double-header engines. The same explanation would also account for the greater creeping down, than up, the grade on double track. On single track where the trains habitually take a running start for a grade, the rails for some distance above the foot of the grade have been observed to creep up grade, due, of course, to the excessive speed of trains going in that direction.

Rails usually creep most on embankments, especially newly-made ones, and little or least on solid, hard ground not raised above the surrounding level. Track laid over swampy or boggy land creeps worst of all, and on some trestles it is not far behind, especially where there is a drawbridge to break the continuity of the rails. The outer rails of double track, on a fill, creep more than the inner rails, because the support for the former is less firm. The records of track inspection apparatus which measures rail deflection, show that almost invariably the rails on the outside of double track are subject to greater average deflection per mile than the inner rails. In tunnels rails creep none or scarcely at all, unless pushed by the rails outside, thus showing that the creeping is least where the foundation is firmest and wave motion least; the nearly constant temperature may also have its effect. M. Couard, a French authority on maintenance of way questions, states that in the Credo tunnel, between Lyons and Geneva, no creeping whatever was discoverable, and on a 2½ per cent grade in the Sauvages tunnel the maximum amount of creeping was only 4 ins. during 9 years of service. On curves where the inside rail receives the heavier load, on account of a too great elevation of the outside rail, the inside rail creeps faster than the outside rail. On straight double track which is out of level the lower rail will creep the faster. The relative amount of creeping of the two rails may also be affected by side pressure against the cars from prevailing winds, which operate to throw a disproportion of the weight to the lee side.

It is of frequent report that the outer rail of curves creeps faster than the inner rail or that one rail (on either curve or straight line) creeps while the rail on the opposite side of the track creeps little or not at all; and some claim to have seen the two rails creep in opposite directions—in fact there seems to be a great variety of ways in which rails will creep. I believe, however, that there are five essential conditions which govern all cases of creeping rails and that a knowledge of the conditions prevailing in any case will enable one to explain all the attending phenomena. I would say that the manner in which rails will creep, and the amount, depend upon: (1) the character of the ground or foundation for the track; (2) the direction in which the train loads are the heavier, if any; (3) the proportion of weight distributed on the two rails; (4) the speed of the trains; and (5) the manner in which the ties are spiked. On a curve the 3rd condition may depend upon the 4th, as, for instance, high speed, where the elevation is too little, will throw the greater portion of the weight on the outer rail, whereas if the elevation of the outer rail be too great for the slow-speed trains the preponderance of weight will fall upon the inner rail; and the rail which receives the more weight, other conditions being equal, will creep the faster. Where there is no relative advance of either rail it is quite likely that the effects produced by heavy, slow-speed freight trains and fast passenger trains are compensating. I have never seen a case where the two rails of a piece of track have crept in opposite directions, but have found explanation for cases of the kind reported. In every instance of the kind which has been brought to my notice there has been a curve at, or in proximity to, the place where the creeping in both directions took place, and there was a marked difference of either speed or tonnage in the trains passing in the two directions. The creeping of rails due to the setting of brakes may have some influence on grades, where no doubt the retarded wheel has a tendency to skid the rail under itself; but here, as in the vicinity of stations, its effect, at most, can be only local. The slipping effect of wheels on curves may also exert some influence on the relative amount of creeping of the two rails, but it is probable that the matters of speed and superelevation, which determine the distribution of the weight between the rails, are of more consequence.

Some of the German engineers who have theorized a great deal on the subject of rail creeping claim that the unequal movement of the two rails is due to the unsymmetrical working of the locomotives. Such action is supposed to result from the phase difference of rotation of the two sides of the locomotive consequent upon the condition that the crank on one side leads that on the other side by a quarter turn, causing side oscillation and greater intensity of pressure on the rail which is on the side opposite from that on which the crank has the lead. Thus, if the leading crank be on the right side the deviating tendency of the locomotive will be toward the left, and the excess pressure resulting from such one-sided action will be on the left rail. These people tell us that on electrically operated roads, where the driving force is not reciprocating, there is no difference in the rate of creeping of the two rails.

Anti-Creeping Contrivances.—It now remains to discuss how the creeping of rails can be prevented or retarded. In the first place, the laying of the rail in sections with open space between the sections being the primary cause of the creeping of rails, the keeping of the splices to a snug fit may lessen the creeping, although it is clear that they cannot be bolted tightly enough to entirely prevent creeping. Again, the creeping may be greatly augmented by having the splices too tightly bolted to allow the rails to expand and contract freely. The bolts should, therefore, be kept turned on to a snug bearing at all times, but not too tight, especially in hot weather. The principal method employed to prevent rails from creeping, or to retard the creeping, is to slot-spike the splice bars; and to get additional anchorage a "dummy" splice is sometimes bolted to the middle of each rail and slot-spiked. Where the tendency to creep is not great, slot-spiking at the joints will hold the rail in check, but where this tendency is strong there may be seen examples numerous enough where, for mile after mile, every joint tie has been shoved bodily by the creeping rails, crowding out the ballast or splitting open the ties, the latter effect occurring principally on bridges. It would seem that in such cases it had indeed been better if no splices had been slot-spiked, and the rails allowed to run unopposed; for then it would only have been necessary to redrive the spikes which the splices had pulled away from, or the spikes which the splices had run against. It is doubtful whether any advantage to be had from spiking in slots at the joints can offset the damage which arises when joint ties are shoved off their tamped and pressure-compacted beds onto the less firm filling material between the ties. Such displacement of the ties weakens the support for the joint and leads to settlement, and much labor is required to shift the ties or square them with the track and tamp them. One roadmaster who for a number of years has kept careful account of track repairs on a double-track road maintained in first-class condition, on gravel ballast, puts the average expense of this item at $14.88 per mile of single track per year. This amount does not, however, cover the cost of raising and tamping low joints, with the shoulder and quarter ties that become low in consequence of the shoving of the slot-spiked joint ties by the creeping rails. The slot-spiking of splice bars is therefore not always a satisfactory means of resisting rail creeping, for in very extensive practice it seems clear that any advantage gained in resistance to rail creeping is compensated by a considerable expense entailed in the work of tamping low joints and in respacing joint and shoulder ties; while in some instances recourse is taken to the laborious process of driving back the rails. Nevertheless, the majority of maintenance-of-way officials seem to regard the method of slot spiking at the joints as of at least some value in resisting rail creeping, even if it does not entirely prevent it.

It is my opinion that where the creeping force is irresistible the joint ties should not be slot-spiked. The principle of so anchoring each individual rail to the ties that it will be self sustaining is the right one, but if the method of anchoring is not effective the fact of having the correct principle in view does not help matters any. No method should be followed which results in derangement of the spacing and bearing of the joint ties. Where the creeping is so bad that it becomes necessary to respace the ties at and in the vicinity of the joints every year I would recommend some other method of anchoring than that of slot-spiking the splice bars. As the weakest part of the rail is at the joint, it seems like putting too many duties on the joint ties to slot-spike them when they cannot be maintained in position. Anchorage at intermediate portions of the rail is usually effected by dummy splices or "check plates" at the centers, and sometimes also at the quarters. The first cost of these devices and the cost of the labor of putting them on is something of an item, to be sure, but if the rail creeps the damage from the dislodgment of center or quarter ties is not nearly so much as that which results from a similar dislodgment of the joint ties; and then, owing to the greater tendency to deflection at the joint than at intermediate parts of the rail, the filling material about the joint ties is more or less shaken up and loosened, so that, as a rule, the ties at the center, quarter or other intermediate points are more firmly embedded in the ballast filling, and therefore better able to resist creeping of the rails. Dummy splices may be had cheaply by cutting up old angle bars, retaining a bolt hole in each piece and slotting the horizontal leg of the piece. Where such practice of anchoring the rails becomes standard all new rails should be ordered drilled at the proper points by the manufacturer. The flange of the rail should never be notched or slotted for the purpose of setting spikes to resist creeping, or for any other purpose. The practice of setting spikes against the ends of splice bars, as is sometimes done in lieu of slot-spiking, should not be followed, as in this position the spikes are extremely difficult to draw.

Resistance to creeping may be much increased by placing blocks between the ties ahead of the anchor plates. For this purpose the sound parts of old ties may be cut into proper lengths (10 to 13 ins.) and split into quarters. By using blocks, one anchor plate at the center of each rail may be sufficient to prevent creeping. The use of long ties is also recommended in cases, particularly on soft or swampy roadbed. To resist creeping under such conditions, a committee reporting to the Canadian Roadmasters' Association recommended ties 10 to 12 ft. long, 7 to 8 ins. thick, spaced 8 ins. apart in the clear, on cinder ballast 18 ins. deep, blocking four ties each side of each joint with pieces of 4x4-in. scantling and using long angle bars at the joints slot-spiked to the ties. One member representing the Canadian Pacific Ry. reported good results under such conditions from having used ties 12 ft. long and 8 ins. thick, on cinder ballast, spiking through the slots of long angle bars at the joints.

Perhaps the most remarkable experience with rail creeping on record has occurred on the Canadian Pacific Ry., where it crosses the Barclay muskeg, about 217 miles east of Winnipeg. Some of the facts regarding the creeping at this point and the method of prevention employed there and elsewhere were given to the Railway and Shipping World, in May, 1900, by Mr. W. Whyte, assistant to the president, Canadian Pacific Ry., as follows: "When the track at this point was laid with 56-lb. steel it used to move under every train, rendering it necessary to keep a watchman on duty there day and night with short pieces of rails to meet the expansion and contraction. I myself, in 1887, saw the track creep while a train was passing over it, 2 ft. 4 ins. In addition to my own personal observations, measurements have been taken of the distance the track crept under a moving train, and these show that a movement occurred in the track of from 2 to 37 ins., depending on the temperature, weight of engine and train, and softness of bottom. To stop this creeping, the length of the ties was increased from 8 ft. to 12 ft., and a slot was cut in the base of the rail over each tie, the slots being staggered, that is the slot over one tie would be on the inside of the rail and over the next tie on the outside of the rail. When the track was laid with 72-lb. steel, 44-in. angle bars were used and the steel was laid square joints, so that the ties would not slew with the creeping. The rails were not notched as above set forth, but angle bars were used on the center of every second rail and spiked to the ties. This is the practice we have been following on muskegs where track creeps. This has had to be done at Oxdrift and Telford with our 73-lb. steel and 26-in. angle bars, which have spike holes punched through them, and which give far better service than the 44-in. angle bar with the slotted holes, as the shoulder was continually wearing off on the latter, rendering the bar useless for holding the rails, and by slipping past the spikes, destroyed the gage of the track. By this means we have been able to stop creeping track, but the joint ties still churn on the muskeg."

A method planned on a principle similar to that of blocking the ties ahead of the slot spiking is to tie the ties together. Such a method has been adopted on the Hungarian State Ry., the arrangement consisting of two long flat plates corresponding to a rail length, crossed and screw-spiked to the ties, inside the rails. In this manner all the ties for a rail length are interconnected or framed together to act as one against rail creeping, the splice bars being slot-spiked to the ties. Where the tendency to creeping is strong this arrangement is repeated for four to ten rail lengths in a place, according to the force to be resisted.

It is important that the means of anchorage on both rails should engage the same tie at each point of application. On square-jointed track this practice follows as a matter of course, because the joints and corresponding points of the rails for both sides stand opposite. The plan of anchoring both rails to the same ties is much more effective than that of anchoring to separate ties, because the resistance of a tie to being pushed bodily through the ballast filling (that is, both ends together) is several times the resistance of one end to being slewed. To follow this plan on broken-jointed track slot-spiked at the splice bars, it is necessary to anchor the center of each rail to the joint ties of the rail opposite; but if it is desired not to slot-spike the splice bars on track so laid, then the anti-creeping devices must be applied at the quarters, the first quarter of each rail on one side standing opposite the third quarter of the rail opposite. The slot-spiking of joint ties on broken-jointed track without placing an anti-creeping device in the center of the rail on the opposite side of the track is usually the cause of a large amount of work necessary to maintain the joint ties in position squarely across the track, and to rectify the gage which is tightened by the slewing of the ties. The recurrence of this distortion of the track and ties is so general and frequent on some roads that the work of replacement cannot be kept up by the ordinary section forces, and this accounts for the fact that it is so frequently neglected for many months at a time.

Of the several forms of anchor plates the most common is a metal clip of some kind bolted to the web of the rail and projecting far enough beyond the rail flange to be notched or punched for a spike. A contrivance which has been used on the Boston & Albany R. R. for a long time, called a "check plate," consists essentially in a tie plate having one end doubled over the rail flange and curved to fit up against the web, to which it is bolted, on the outside of the rail. The doubled edge of the plate is slotted for a spike and at the inside edge of the rail flange the plate is punched for two spikes. The track is broken-jointed and this device is applied to the rail center, opposite each joint. Use has also been made of a special plate to lie under the rail and extend over the next tie beyond the joint tie or ahead of the check plate. As applied at the joint, it is punched on one end to receive the spikes driven through the slots in the splice bars and at the other end for spiking to the tie over which it extends. As applied at the check plate, one end edge simply abuts against the check plate and the other end is punched for spiking to the tie beyond the check plate. Wooden blocks between the ties for two or three spaces ahead of the anchor plate have also been used on this road with good results. The Bonzano anti-creeper consists of a twisted strap, about $\frac{5}{8}$x$2\frac{1}{4}$ ins. in section, of sufficient length to be spiked to two ties with one tie intervening. The middle of the strap is bolted to the rail web and the tail ends are spiked to the tops of the ties through punched holes.

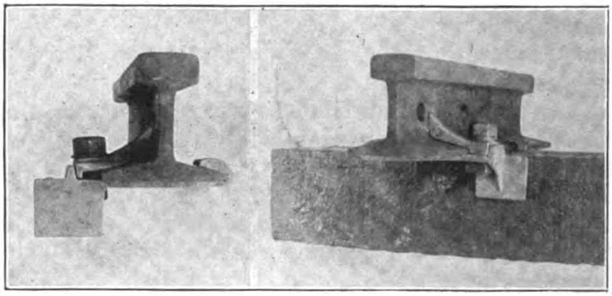


Fig. 265.—Laas Anti-Creeper, C., M. & St. P. Ry.

The application of the foregoing devices to the rail is a matter of considerable expense, as the rail must be drilled for bolting; and then the drilling of the rail fixes the point for the application of the anti-creeper, affording but little or no leeway for respacing the ties in the vicinity of this hole when tie renewals are being made. Mr. E. Laas, while roadmaster with the Chicago, Milwaukee & St. Paul Ry., designed and put into service an anti-creeper which can be applied to the rail at any point, except at the joint splice, without drilling the rail. It is a malleable iron skew clamp with a depending lug, or tail piece, bolted to the flange of the rail, as shown in Fig. 265. There is a plate hooked over the rail flange and formed into the depending lug, about $2\frac{1}{2}$ ins. deep, on the outside of the rail, which engages the side of a tie. This plate is bolted to a dog clamped to the top side of the rail flange and extending to the web. The oblique position of the clamp gives it a gripe on the rail which is sufficient to prevent the slipping of the rail through the clamp. As the device can be applied to any part of the rail, except at the joint, it may always be placed to engage a sound and well bedded tie, and as it is not spiked to the tie, no injury is done to the same, as is sometimes the case where the crowding of the creeping rail against the spike will split open the tie. Since it is not advisable to slot a splice bar at or near the middle, no measure is usually taken in general practice to anchor the rail to supported joint ties. In the case of long splices slot-spiked to the two shoulder ties, the creeping of the rail will "bunch" the ties together, shoving the shoulder tie against the center tie and carrying the joint off the latter. To prevent such derangement of the tie spacing under long splices, Mr. Laas designed and put to service another anti-creeping device which is bolted to the splice under the head of one of the middle bolts in position to engage the side of the center tie, as shown in Fig. 266. It consists of a malleable iron clip or lug hanging some 2½ or 3 ins. below the base of the rail, with a shoulder under the rail to prevent the device from swinging upward when the movement of the rail forces it against the side of the tie.

The application of measures to prevent or resist rail creeping on bridges or trestles having open floors is usually restricted to the track on the grade, no stop devices being permitted on the structure. The rail, if not held back on the grade, is then free to creep over the bridge unopposed. Nevertheless, slot-spiking of rail splices on bridge ties in connection with anti-creeping measures on the grade, is sometimes practiced with reported satisfaction. In such cases blocks are placed between the ties to catch the slot spikes wherever the timber guard spacing does not permit the tie to come under the slots in the splices. One of the roads on which slot-spiking of splice bars on bridge ties is required is the Southern Pacific lines west of El Paso. The instructions regarding anti-creeping measures to be taken

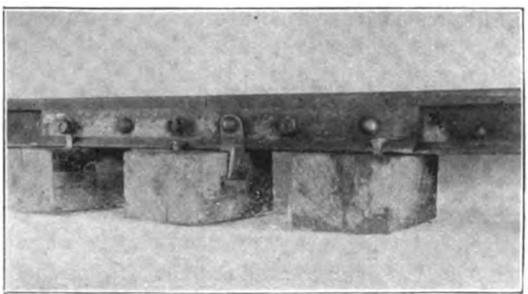


Fig. 266.—Laas Anti-Creeper for Supported Joint Ties.

on the bridge approaches are as follows: "Where rail shows so strong a tendency to run as to shift the ties along the roadbed, on each side of the structure, this tendency will be prevented by bolting the joint ties together for as many joints as may be necessary to stop this movement." The standard distance between joint ties is 8½ ins., and to preserve this interval old cast iron spool stringer separators, adding a few old cast washers to make up the 8½ ins., are used between the joint ties, directly under each rail, and the ties are bolted together with old ¾-in. bridge bolts 27 ins. long. Where the tendency to creep is unusually strong a pair of angle bars is bolted to the center of each rail, opposite the joint on the other side (broken-jointed track), and slot spiked, thus securing an anchorage every 15 ft. As a general proposition the practice of slot-spiking on bridge ties is not safe unless the creeping of the rails can be entirely prevented. In one case where bridge ties were securely fastened to the stringers and the splices slot-spiked, the creeping of the rails pushed the bents of a pile trestle a foot out of plumb, and in another instance a 154-ft. bridge span was shoved endwise 3 ins. in one season.

On long bridges or near the ends of the same expansion or slip joints are sometimes used to permit the rails on the bridge to expand or creep without hindrance, or to prevent the rails on the grade from shoving those on the bridge. In some instances these expansion joints consist of rails halved together for a distance of 12 to 24 ins. at the ends and firmly secured to a base plate, and in other instances they consist of switch points and stock rails, as in Fig. 211, already described in connection with drawbridge joints (§ 80, Chap. VI). A most remarkable example of the application of the latter type of expansion joint, when taken in connection with the attending conditions, is at the Eads steel arch bridge over the Mississippi river at St. Louis. The east approach to the bridge is a steel viaduct 2500 ft. long, on a grade of 80 ft. per mile, and on the bridge proper, which is 1600 ft. long, there is a rise of 5 ft. at the center. The line across the bridge is a double track, and the rails creep in the direction of the traffic, up the approach grade and across the bridge on the west-bound track, and in the reverse direction on the other track, with a force sufficient to fracture splice bars and shear ⅞-in. bolts. The rate of creeping on the bridge is about 16 ft. per month for each track, and on the viaduct about 37 ft. per month for the west-bound track and 44 ft. per month for the east-bound track, although the actual amount of creeping varies with the traffic. In former years a gang of five trackmen were employed by day and a gang of three at night to remove and replace pieces of rail to adjust for the creeping, but eventually expansion joints, locally known as "creeping plates," were put in. Of these there are eight—one in each track at each end of the bridge and at the east end of the viaduct, and one in each track to protect a crossover on the viaduct near the point where it joins the bridge proper. Figure 267 is a picture of the so-called "creeping plate" on the west-bound track at the west end of the bridge, the direction of the traffic and of the creeping being toward the observer. The set of disconnected switch points (A) is rigidly bolted to the guard rails (B), to a 2-in. flangeway, and both are anchored to steel plates (1 in. thick and 6 ins. wide) on the ties. The main rails (C), called the "sliding rails," are secured to these heavy tie plates by clips which engage the top of the flange but leave the rail free to creep, and do not interfere with the fish plates on the joints as they creep over the plates. As the creeping proceeds, say on the west-bound track over the bridge, rails are coupled on and gradually drawn through the creeping adjuster at the east end while rails are being pushed out of the adjustment device at the west end. As often as rails are released at the west end they are carried and started in at the tail of the procession on the other track. In this manner the rails are continually traveling in a circuit without interrupting the traffic.

Many practical students of rail creeping regard loose or improperly arranged spikes as the conditions most largely conducive to such movements, and claim that timely attention to these details will avert the trouble. Thus, it is frequently reported that the practice of holding up the ties and driving down the spikes to a snug bearing on the rail flange, once or twice each year, has stopped rail creeping, without the use of special anti-creepers, and that in cases where slot-spiking of the splice bars had failed. In order to increase the anchoring effect of the spikes in their hold upon the rails, there is a method of spiking known as "cross binding," or so staggering the spikes that they clutch the rail whenever there is a tendency to creep. This arrangement is to have the outside spikes on each rail lead the inside spikes in the direction in which the rails tend to creep. Referring to Fig. 268, the spikes A and E on tie X lead the inside spikes D and F, the arrow points denoting the direction of the creeping tendency. It will be apparent that if the rails tend to creep, the spikes A and D will clutch the rail and the tie will resist the creeping movement. The least movement of the end of the tie X with the rail R causes the spikes A and D to make tighter contact with the rail and the spikes E and F to lose contact. On the other hand, and to show contrast, any movement of the end of the tie Z with the rail R, swings spike B outward from the rail and spike C inward from it, causing them to lose contact, and, consequently, the tie does not resist the rail. So, then, if the rails R and R' creep or tend to creep in the direction of the arrows, either R will be clutched by the spikes A and D, or R' by E and F, depending upon which end of the tie is the easier started; while any tendency in the rails to move in the opposite direction will be opposed either by spikes B and C clutching R, or H and G clutching R'. Here is no doubt an explanation for the fact that one rail sometimes creeps while the rail opposite creeps little or none—the spikes in the vicinity happen to be so driven that they clutch the rail on one side of the track only. On double track, or on down grade on single track, or where for any reason the tendency is for the rails to creep in only one direction, the spikes in all the ties should be driven alike, and so as to cross bind the rails for that direction only; as, for instance, the spikes in tie X, for the direction indicated by the arrows; in which case, presumably, half the ties will clutch or cross bind each rail. At any rate, as some of the ties under each rail will clutch and resist it when the spikes are driven

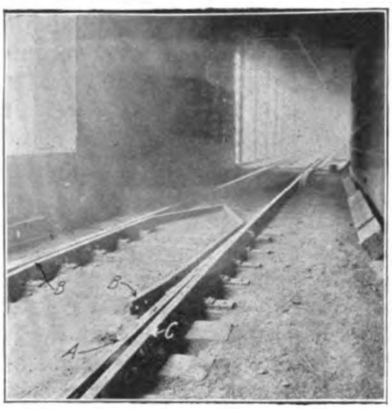


Fig. 267.—Creeping Adjuster at Eads Bridge.

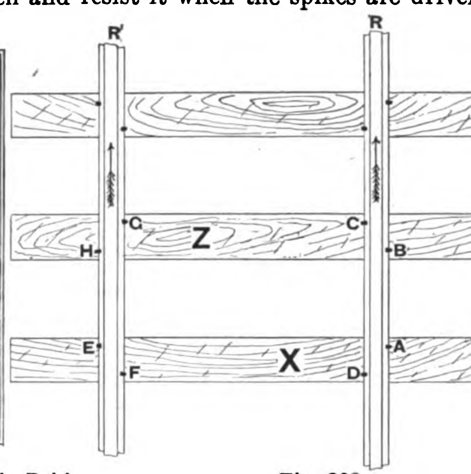


Fig. 268.

cross binding, while others will clutch and resist the other rail, be they divided half and half or not, they certainly strongly oppose creeping, and if the rail does move they tend to carry it back to its place after the impelling force ceases to act. This system of spiking, in connection with slot-spiking, has been known to stop rails from creeping where slot-spiking every angle bar has failed. Where the system is pursued on broken-jointed track an exception should be made with the position of spikes on the end of a tie which is opposite to a slot-spiked splice bar. In that case the end of the tie which is slot-spiked must necessarily move with the creeping of the rail, and if at the other end of the tie the outside spike is leading the inside one, the least swinging movement or slewing of the tie will cause these spikes to lose contact with the rail. If, however, their regular position be transposed, they will lock to the rail and resist the creeping tendency. By way of illustration, suppose the spikes D and A are driven in the slots of splice bars in that position, then the spikes E and F on the opposite end of the tie should be transposed, or set with spike F leading, so that any movement of the rail R causing the tie to slew in the direction of the arrow, will lock these spikes to the other rail—in the position shown they would lose contact under such a movement.

If the cross binding of the spikes is not done when the track is laid, it should be attended to in tie renewals, and every spring the section men should go over the track and drive down the spikes, so that the heads have a snug bearing on the flange of the rail, holding the ties up to the rail with a bar, wherever necessary. It is hardly possible to entirely stop the creeping of rails in every case, but if proper attention is paid to the matter it can, in most instances, be so resisted that it will cause but little trouble. Heavy rails, being stiffer than those of lighter section, are subject to less undulatory movement and consequently creep, or tend to creep, less. The laying of 100-lb. rails in track over swampy ground, where creeping was troublesome, has been known to stop the creeping entirely. As already explained, low joints, or rough track, in hot weather especially, facilitate creeping, and if the track has insufficient ballast filling between the ties the efficiency of anchor plates, slot-spiked splice bars or other anti-creeping arrangement is impaired.

104. Shoveling Snow.—As soon as snow begins falling the foreman should equip men with brooms and shovels and start them going to and fro over the switches, to keep the points clear of snow. If the switches are widely separated or are located in groups some distance apart, it may be necessary to give some attention to the detailing of the men, so as to cover the work most effectively and avoid loss of time which might occur from walking over long distances. A pretty good practice is to scatter a few handfuls of rock salt around the switch points, guard rails, frogs, and switch rods to keep the snow melted as fast as it falls. It is not so well to place salt around road crossings or wherever it will be retained, because several years' use of it under such conditions will corrode the rails badly. The bad effects of salt on joints, bearings or moving parts may be neutralized or prevented by the application of oil as soon as the snow is melted. Some make it a practice to take a brush and smear the rails with a coating of black oil and kerosene mixed, as it prevents the snow from adhering to the rails and causes metal parts to shed water quickly when the snow melts. All guard rails, frogs, highway crossings, point switches, signal and interlocking connections, and the angular spaces about frogs and switches should be kept clear of packed snow and ice.

Soon after snow stops falling the men should turn their attention to the flangeways at the road and street crossings, and the gage side of the rails, all along the track, should be flanged out, not as a matter of safety but to make room for the wheel flanges, so that freshly fallen or drifted snow may be crowded out of the way and not become a hindrance to the adhesion of the drivers. Such work should not be delayed with the expectation that thawing weather will remove the snow before another storm occurs, for fresh snow on top of old snow that is packed down forms a serious obstruction to traction almost as soon as it begins falling. Where a train flanger is not to be used or where the snow has thawed and frozen into ice, this work must be done by hand, picking being necessary in the latter case. If there are grades on the section it is well to flange out the track on the grades first, giving early attention also to stretches of track within starting distance of the stations. Figure 269 shows a snow flanger made to be pushed by hand on one rail at a time. The mold board is of sheet steel ⅛-in. thick and 3 ft. long, set at an angle of 45 deg. with the rail. The frame is carried on two 4½-in. double-flanged wheels set 12 ins. centers, and the hight of the pushing handle is adjustable by means of the link shown. At one time the Pennsylvania R. R. and Lines West of Pittsburg had 200 of these machines distributed among the section men, but since flangers attached to locomotives have been adopted these machines have gone largely out of service. The use of this flanger is said to have been quite satisfactory, as a hand device, being much more efficient than hand shoveling. Three men with one of these machines would ordinarily flange six miles of single track, in good shape, in a day, working in snow up to 8 or 10 ins. depth if it happened to be that deep. For heavy work, as in hard-packed snow, assistance should be rendered by extra help, pulling on a rope attachment.

Snow should be removed from side-tracks as soon as it stops falling. Trains may keep the main track clear, but a freight train attempting to enter a side-track where the snow lies at full depth is liable to be stalled. When deep snow falls it is also necessary to shovel out the turntable pits. Scoop shovels are best for handling light snow. Switch stands also must be looked after attentively, as a freezing sleet will sometimes freeze switch stands so solidly that they must be thawed out before they can be thrown. This can be done by burning a piece of oily waste on a stick or shovel and holding it under the frozen bearing. The Elliot double latch "Snow Cap" switch stand (Fig. 123) is designed to protect the bearing of the main shaft in the top table from sleet and snow and thus prevent the occurrence of trouble of this kind. To keep ground switch stands, especially those with gear movement, from clogging up or being covered up with snow it is to

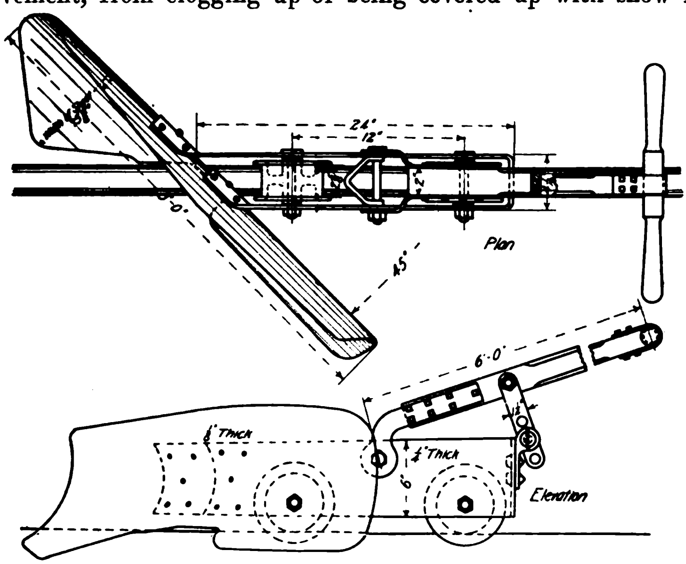


Fig. 269.—Hand Snow Flanger, Pennsylvania R. R.

some extent the practice to cover the stand with a gunny sack or piece of old carpet, while snow is falling. In order to have tools conveniently at hand for clearing switches of snow, use is made on a number of roads of a "shovel post" or "broom post" set a few feet beyond the end of the head-block. It has a peg on which is hung an old shovel or a broom, for use when the switch points are snowed under or packed about with snow. Such an arrangement is especially convenient at outlying switches, where close attendance is not liable to be had. In this way the tools are available at all times to the track-walker or the trainmen, and at times when snow is falling fast they are much needed. On the Union Pacific R. R. this post consists of a piece of old boiler tube stuck into the ground. Near the top of the tube, which stands about 3 ft. out of the ground, there are hooks for hanging the switch lamp during daytime, or a shovel, and a splint broom, with its handle stuck down the tube, is kept on hand for sweeping snow.

During winter, at such private crossings as will not be used, the planks each side each rail should be taken up, so as to reduce the work of cleaning flangeways, and also to avoid trouble liable to arise at such crossings through the planks being loosened or crowded out by snow packed in by the wheel flanges. Taking up the plank at such times also removes obstructions to snow flangers. When snow is to be "bucked" and there are cuts filled with snow, it is sometimes the practice to have the trackmen shovel out sections of about a rail's length in a place, 10 ft. wide, skipping a rail's length between sections. When such work is under way a lookout should be posted at some point above the cut where he can see both ways along the track, so as to give warning to the men shoveling in the cut in case a train approaches. Foremen should take no risk in sending men into a cut; it is dangerous unless there is a way for the men to get out easily and quickly. At each end of the cut it is usual to shovel the snow away until a depth of at least 3 ft. of snow is reached, so as to hold down the nose of the plow at the entrance, in case the snow should pack hard and freeze. When a snow plow is run over the track the section men should follow after it and remove heaps of snow from the highway crossings, from turnouts and other places. Cuts are sometimes widened out by shoveling the snow onto flat cars and hauling it away.

105. Oil-Coated Ballast.—Discomfort to passengers from dust stirred up by fast trains is an important consideration from a traffic point of view, and particularly with railway companies which depend largely upon summer resort or pleasure travel. On not a few roads which handle a large passenger traffic a means of preventing this annoyance is in practice. The remedy consists in the application to the surface of the roadbed and track of a heavy oil of low cost, the oil, penetrating for some inches below the surface, having the effect of laying the dust present and of collecting what may afterwards settle or be blown upon it. The principle upon which the effectiveness is claimed is that the oil sinks into the ballast and prevents dust from flying by holding it down. Its action differs from that of water, in that water prevents dust by making mud, and after it evaporates the dust is as bad as before; while the oil evaporates but very slowly, so that spraying is required but once a season. This method of laying dust is the invention of Mr. J. H. Nichol, assistant engineer with the West Jersey & Seashore division of the Pennsylvania R. R., where the treatment was first inaugurated by him in the spring of 1897. The earliest roads to make ex-

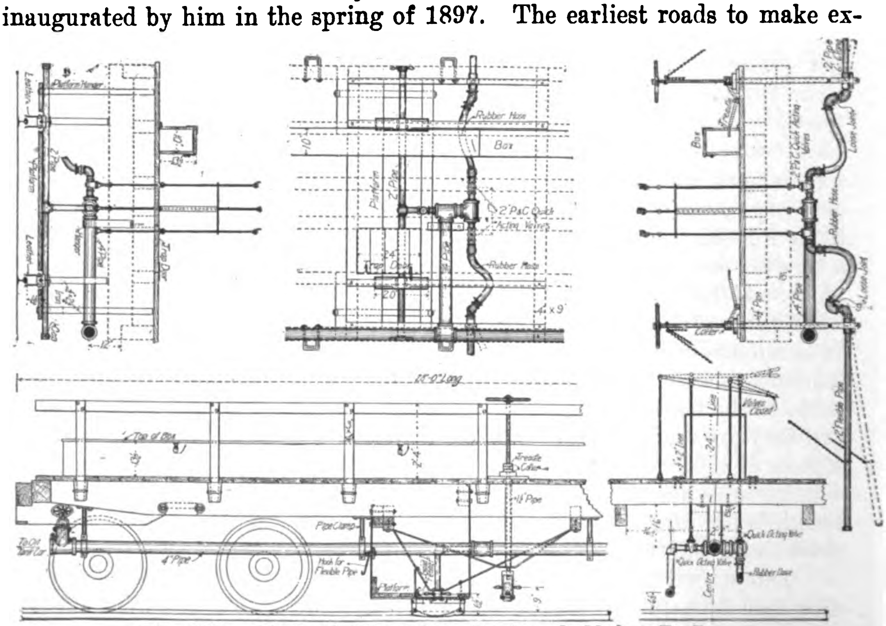


Fig. 270.—Oil Sprinkling Car, Boston & Maine R. R.

tensive use of the treatment, in addition to the above named, were the Philadelphia, Baltimore & Washington and seacoast lines of the Pennsylvania R. R., the Long Island R. R., the Boston & Maine, the Boston & Albany, the New York, New Haven & Hartford and the Delaware & Hudson.

The oil used is a by-product of petroleum distillation, the grade giving best satisfaction having a specific gravity of about 0.887. It is known by the trade name of "roadbed oil," and the cost, in different years and in different localities, has been 2 to 3½ cents per gallon. It is high test, and under the conditions in which it is used it is practically noncombustible. On this point it is said that fewer ties are burned on oiled track than on track or roadbed not so treated. The sprinkling apparatus is arranged on and under an ordinary flat car. One of the cars used on the Boston & Maine R. R. is illustrated by Fig. 270 and the details of the equipment are briefly as follows: A 28-ft. flat car is used and a 4-in. supply pipe is hung 12 ins. below the side sill, on one side of the car, and provided with couplings at either end for connecting with an oil-tank car. Connection with the oil-tank car is had by 4-in. hose, 24 ft. long. At the middle of the car a branch pipe of the same size leads crosswise the car to a "T," where connections are made with a 2-in. stationary distribution pipe 8 ft. long, resting upon hangers, crosswise the track, 6½ ins. above top of rail, for sprinkling oil in the track; and to flexible rubber hose connections with 2-in. pipe 6½ ft. long swung from either side of the car, for sprinkling the roadbed beyond the ends of the ties. Special hose connections may also be provided with hand sprayers, for sprinkling parts of the roadbed beyond the reach of the fixed pipes. The flow of oil escapes from the distribution pipes through slit openings 3 ins. long and 1/16 in. wide, in the bottom of the pipe, the openings being spaced ¾ in. apart. The ends of the pipes are capped, as shown. The adjustment of the swing sections is effected by chain and hand wheel, so that the pipe may be held to conform to the slope of the earthwork, be it in a cut or on a fill. These side sections are yielding, so as not to be broken or torn loose by meeting with an obstruction. Alongside the distributing pipe which hangs underneath the car there is a wooden platform suspended from hanger irons, access to which is had by a trap door through the floor of the car. On this platform, while the car is in service, a man is stationed with an implement to open oil passages that become clogged. Hanging from the under platform, each side each rail, there are leather flaps serving as guards to keep the rail clear of oil. The flow of oil into the distributing pipes is controlled by three 2-in. quick-acting valves operated by levers above the decking of the car. Running the length of the car there is a box 13½ ins. high by 10 ins. wide except for 5 ft. of its length at one end, where it is 3 ft. wide. This box is used for stowing the 24-ft. hose, together with other parts of the equipment when not in use. In operation the car is pushed ahead of the locomotive.

The oil is applied to the surface of the track, to the shoulders at the ends of the ties, and for a distance over the slope in cuts and on fills. In warm weather the oil is so thin that it flows sufficiently well by gravity, but steam or air pressure for the blast can be taken from the locomotive, if need be. The sprinkling train is operated by four men, including engineer and fireman, and covers 3½ to 4 miles per hour, while working. Tank cars are previously distributed at sidings along the line, to be picked up as oil is required. On first application 2000 to 2500 gals. of oil per mile of single track are required, and the penetration into the ballast is from 1 to 4 ins. During succeeding seasons less oil is required. The penetration deepens with each application, being found 8 ins. deep, or reaching below the bottoms of the ties, in some cases. At this depth no dry ballast is thrown up in process of tamping or in tie renewals, and therefore no special application is required after such disturbance of the ballast. The general practice is to delay the oiling treatment until after the tie renewals have been completed for the season, which makes it an inducement to push this work along promptly, in order to get the ballast filling into settled condition early. It is also desirable to have the track in fair surface before the oil is applied; the filling should be carefully dressed, the track and shoulders cleared of vegetation and the ditches cleaned. Where the ballast is worked over to a considerable extent later on, as in surfacing, local applications are sometimes made with a hand sprinkler. On fine sand ballast the oil does not penetrate deeply—usually only 1 or 1½ ins.—and has a caking effect; that is, it forms a thin crust over the surface.

As a means of preventing the raising of dust the oil treatment of roadbed is conceded to be very efficient. Where clouds of dust had formerly followed in the wake of trains no dust is lifted after the application of the oil. It is most needed on gravel and cinder ballast and on seashore lines built on sandy roadbed or on track ballasted with sand. Aside from its value as a preventive of dust there are other claims. A direct benefit derived from the laying of dust is a reduction of wear to journals, locomotive parts and all exposed moving machinery on the trains, and particularly a decrease in the number of hot boxes. It is thought that drainage is assisted materially, since rain water falling on treated track is collected in small puddles and runs off over the slopes or into the ditches alongside, where otherwise the ballast would absorb the water. It is said that the soaking of rain into treated ballast which has been disturbed in repair work will float the oil to the surface, thus renewing the coating. This water-proofing quality of the treatment should afford valuable protection during thawing and freezing weather, when the heaving of track depends upon the amount of moisture retained in the ballast and roadbed. The growth of vegetation in the ballast is retarded and the oil, which is very penetrating, is thought to be of some value as a preservative of the ties, being water-repelling at all events. It is the testimony of experience that considerable oil follows the spikes and soaks into the surrounding wood fiber for a distance of about an inch, causing the spikes to work up more readily than is the case on untreated roadbed; but no trouble of a serious character is reported to have been observed from this cause.

Aside from its use on roadbed continuously, the process is applied quite extensively at dusty highway crossings, through dusty yards and through towns, on rock-ballasted roads where the use of a dust layer is not needed except at such places as the ballast is liable to be excessively dirty from outside conditions. Occasional sprinklings at road crossings are made by hand. Of further interest on this subject it may be stated that in California considerable use is made of the oiling process to lay the dust on the public highways, including county roads. On the French State Railways creosote residue has been used experimentally to lay dust on track.

106. Laying Tie Plates.—The increasing use of tie plates, consequent upon increased weight of rolling stock and the use of a larger proportion of soft wood ties, has prominently shown the importance of careful work in setting the plates. Failure to prepare an even bearing for tie plates results in buckled plates, and careless work in embedding the plates gives uneven gage. Experience has demonstrated that the full benefit of tie plates cannot be realized unless attention is paid to the proper setting of the plates. The expense for the labor of setting tie plates is also a matter not to be overlooked. The cost of applying a single tie plate is no doubt regarded as a trifling matter, yet when multiplied several hundred thousand times, or several million times, which measures the scale on which some of the larger railway systems have invested in tie plates, it becomes a subject of no inconsiderable importance. To the various questions pertaining to the subject a good deal of study has been given, in consequence of which several methods of doing the work and numerous special tools have been devised and put into service.

The work of tie-plating track is necessarily divided on two general lines, namely, that of plating ties before they are laid in the track, which applies to track construction and to tie renewals; and the plating of ties already in the track. In the former case the work is comparatively simple, as access to the rail seats on the tie is unobstructed, and the force necessary to embed the flanges or claws of the plate into the tie can be conveniently applied. The usual method of procedure is to take the ties from the piles, before they are distributed, and drive the plates to a proper seat with some striking instrument, which may be a heavy sledge hammer, a beetle or wooden maul, a paver's rammer, an oak tie bored and fitted with two hammer handles at right angles, or a piece of rail with cross-bar handles. To protect the tie plate from bending or other injury by hammer blows, and to distribute the force of the blow, it should be covered with a thick metal plate or driving block. The tie plate should be set to center over the bottom face of the tie, and should be driven far enough to cause its under side to take a firm bearing on the tie. If the plate is not centered on the tie the latter is liable to cant, and unequal bearing will result. If the top face of the tie is winding one of the seats should be adzed to the plane of the other. At the Las Vegas (N. Mex.) tie preserving plant of the Atchison, Topeka & Santa Fe Ry. the ties are run through a spotting machine, which levels off seats for tie plates or for the bases of the rails, wherever any unevenness exists. Tie plates should be set squarely on the ties. If there is any difference in the margin outside the spike holes on the two ends of the plate, the latter should be set to bring the wider margin outside the rail. Before setting tie plates which are punched for rails of different widths of base, a clear understanding should be had concerning the end of the plate which corresponds to the gage side of the rail; otherwise, mistakes are liable to happen which may make it necessary to move the plates when relaying with rails of the changed section. Drawings are usually supplied by the engineering department explaining the manner in which such plates should be laid, and for convenience of the trackmen the shape of one of the holes punched for the gage end of the plate is made to indicate the section or weight of the rail for which it is intended. In cases where unusual difficulty is experienced in maintaining rails to gage on curves, it is sometimes the practice to dap the ties for tie plates, to give the outer rail an inward cant. On the Burlington, Cedar Rapids & Northern Ry. such practice is general for both rails, and on tangents as well, the ties being adzed so as to set the plate to cant the rail slightly inward, causing a bracing effect which counteracts any tendency of the rail to tilt outward. Such practice is, however, unusual in this country. Regarding the time of application, it is the custom with some roads to embed the plates in the ties during winter, so as to get the work out of the way before the tie renewing season opens.

In setting tie plates it is desirable to have some form of tool for quickly locating the position of the plates on the ties, so as to facilitate speed in laying the plates and insure that the plates will be laid in the exact position for the rails properly gaged. For such work there are various styles of gaging tools in service. A common way of proceeding is to set the first plate to a mark on the line side, and then gage the second plate from the first as already driven, using a gage rod having lugs to fit the spike holes. On the

Burlington, Cedar Rapids & Northern Ry. a gage is used in setting the line plate, instead of drawing a mark across the tie face some fixed distance from the end. This gage consists of a strip of boiler iron with a rectangular opening cut in it to hold the plate while it is being driven, the end of the piece of boiler plate being bent down to hook over the end of the tie. On the Boston & Maine R. R. use is made of a double-ended gage working somewhat on this principle, for holding both tie plates simultaneously the exact distance apart to seat the rails at gage. The gage, which was designed by Roadmaster Louville Curtis, is made of wought iron and has a rectangular opening at either end just large enough to receive the tie plate and hold it in position while it is being driven into the tie. Figure 271 shows the dimensions. The center piece is 2½ ins. wide, and ¾ in. thick, and the gaging

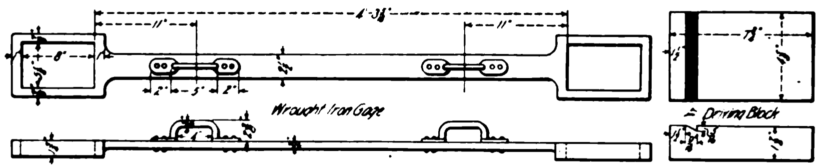


Fig. 271.—Curtis Gage for Setting Tie Plates, B. & M. R. R.

ends are 1¾ ins. thick, being made heavy, so they will not break in case they are struck by a spike hammer. In advance of the work of setting the plates the ties are carefully inspected, and if necessary are prepared for receiving the plates in proper position. If the tie is more than one inch longer than the standard length it is sawed off to the right length. The center of the tie is marked, and if there is any wind in the face the seats for the tie plates are adzed to a plane surface. The tool for testing ties for warped face is a "leveler," consisting of a stick of suitable length with small rectangular frames set in the same plane and nailed fast at the two ends. The tie plates are driven to a seat by means of a driving block and sledge. The driving block, shown also in the figure, is a soft steel plate 7¾ ins long, 4⅝ ins. wide and 1⅛ ins. thick, grooved to fit over the shoulder of Goldie tie plates. The manipulation of the tool is simple, all that is necessary being to place the center of the gage over the center mark on the tie and set the plates into the gage openings. It can be made for setting tie plates of any pattern and is


Fig. 271 A.—Tie Plate Setting on Boston Elevated Ry—Fig. 271 B.

Fig. 271 C—Gaging Tie Plates on a Curve, Boston Elevated Ry.

not patented. The tie plates used on the Boston Elevated Ry. were set with gages of this design.

The work of laying tie plates on an elevated structure or on a bridge floor must be more carefully attended to than when applying them to ties on a graded roadbed. On the earth roadbed the track can be thrown into alignment after the rails are laid, but on a bridge floor it is, of course, necessary to bring the rails to correct alignment before the spikes are driven, and this requires very careful work in bedding the plates. The ties used on the Boston Elevated Ry. were of hard pine, and the plates were all set and embedded before the rails were laid. The tie plate used was of the Goldie claw pattern with a shoulder, making it necessary to embed the plate exactly to position, so as to bring the shoulders of all the plates in line. Figure 271A shows two rows of these plates on tangent, seated in advance of laying the rails. For laying plates on the curves use was made of a tool having an opening for a tie plate on one end and an upward bend and hook on the other, as shown in Fig. 271C. After the running rail and guard rail were laid on the inside of the curve the hook end was held in engagement with the service side of the guard rail by means of a stick, so that the rectangular opening at the other end of the gage would bring the tie plate exactly to position for the rail. Figure 271B shows tie plates set in position for a switch lead, both on the curve and on the straight lead, between the frog and the heels of the point rails.

The Kiley tie plate gage, devised by Mr. John Kiley, foreman of the Salamanca (N. Y.) yard of the Erie R. R., and used satisfactorily in laying a great many tie plates on that road, has a hook arm which gages the position of the plates from the end of the tie. This gage is shown by sketch in Fig. 272. The essential parts are a fixed head (*A*), a connecting bar or pipe and an adjustable head (*B*) secured to the cross bar by means of a thumb-screw. Attached to the head *A* there is the hook arm *D*. Each head piece of the gage is stamped out of a single piece of sheet steel. The head *A* has a rectangular space in which to place the tie plate, and out of the vertical portion there are cut two lugs (*C*), which are bent over so as to leave two upright projections (E), the purpose of which is explained in connection with the use of the gage in applying plates to ties already in the track. The portion of the plate between the lugs C is bent over backward and shaped in tubular form to receive one end of the connecting rod, which is firmly riveted thereto. The adjustable head B is formed by bending a plate at right angles and bending over the edges to form a lapped tube to receive the thumb-screw and engage with the connecting rod, which is graduated to indicate the gage of the heads. This head also has a rectangular space for setting the tie plate. In using the gage on new ties the head B is adjusted to the proper gage distance and the surface plates of the two heads are brought into the same plane. The tool is then laid on with the hook caught over the end of the tie, and if the face of the tie is warped or twisted the rail seats are adzed to conform to the surface plates. One of the tie plates is then placed in the rectangular space in the gage head, when the

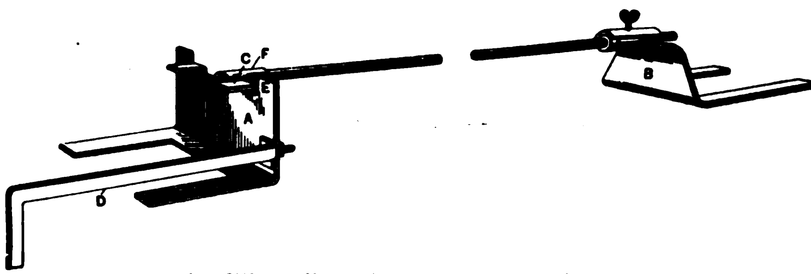


Fig. 272.—Kiley Tie Plate Gage, Erie R. R.

gage is removed and the plate is embedded with a wooden beetle, or other driving tool. The gage is then placed back on the tie to give the position for the second plate with relation to the plate previously set, when the second plate is embedded. If desired, however, the person manipulating the gage may pass rapidly from tie to tie, marking the position of each tie plate with a pencil or scratch-awl, so that a number of men may be engaged at embedding the tie plates at the same time. The tool may be used across the lead rails of a turnout without interference from rails which come between the heads of the gage, as the connecting rod is high enough to clear them.

The tool that is perhaps most widely used for gaging tie plates is the Ware "surfacer" and gage, designed by Mr. Henry Ware, roadmaster with the Buffalo, Rochester & Pittsburg Ry. As illustrated in Fig. 273, it consists essentially of a rod or piece of pipe joining the heads of two flat metal plates called "surfacers," the rod being fixed to one of the heads and adjust-

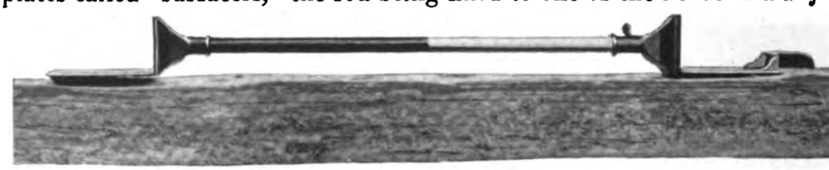


Fig. 273.—Ware Tie Plate Gage (Testing Rail Seat Level).

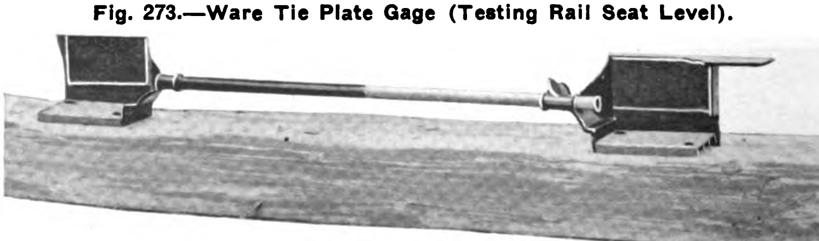


Fig. 274.—Ware Gage (Locating the Tie Plates).

able with the other by means of a thumb-screw. To apply the tool to new ties used either in track-laying or in tie renewals, the heads are adjusted by the graduation of the rod to the proper distance apart to correspond with the gage of the track and the dimensions of the tie plates to be used. The surfacers are brought accurately into the same plane and set tightly therein by the thumb screw. Where hewn ties are used it is necessary to inspect the upper face to see that the seats for the rails are in the same plane. This inspection is made with the tool, and if the seats are out of true they are adzed to the proper level to meet the surfacers, as applied in Fig. 273. The tool is then turned partly over, as in Fig. 274, and the plates are placed on the tie to proper gage and settled to place with a beetle or other tool. In practice it is customary to first embed one of the plates and then put the tool back on the tie and place the second plate accurately to conform to its required position with relation to the plate first embedded. After the plates are set the tool can be applied, as in Fig. 273, to test the surface level of the tie plates.

Fig. 275.—Machine for Plating Ties, S. F. & S. J. V. Ry.

The foregoing methods and tools for setting tie plates by hand are quite generally applied, but in plating ties for new track construction on a large scale power machinery has been used for the purpose, notably in the building of the San Francisco & San Joaquin Valley Ry., when more than one million ties were plated. The ties used were redwood, with 5x8-in. Servis tie plates, and the work was so extensive and so rapidly pushed that some means for cheaply and quickly applying the plates before the ties were distributed on the roadbed was desirable. The machine used consisted of two presses, as shown in Fig. 275, with rollers to assist in the movement of the ties into and out of the presses; and of a 15-h. p. boiler to furnish steam to operate the presses. The general scheme of the operation of the machine is obvious from the illustration. The tie is shoved over a series of rollers, on horses, until it enters the presses, where it is held in proper position by a stopping device which appears at the right hand. The plate for each end of the tie is inverted and placed upon the plunger of the steam cylinder, which works from underneath. The plate comes between two rollers and is low enough to be out of the way as the tie is shoved to place. Between the presses there are two pairs of clamps which are opened up (they appear in the closed position in the illustration) before the tie is shoved in, and attached to these clamps there are side levers for moving the tie into line and centering it over the plates before the pressure is applied. The position of the two presses is adjusted for properly gaging the plates and the pressure is applied to the two plungers simultaneously, lifting the tie vertically against the tops of the presses and forcing the plates into the tie. After the plates have been pressed home the tie is dropped down into its original position and pulled out at the end opposite from that at which it entered the presses, the stopping device being dropped by the lever and link arrangement shown. The presses are adjustable to the extent that they will allow ties of varying thickness and width to be used.

The operation of the machine required at least seven men—two to shove the ties into position, two to place the plates, one to apply the power and two to remove the tie after the plates had been forced into place. When first received the machine was used on a car. This car being started at one end of a long pile of ties worked slowly through the same, the ties then passing either to a pile on the other side of the car or directly to cars for shipment to the front. While handling ties in this way the capacity of the machine was about 3000 ties plated in ten hours. Continuous working, night and day, was sometimes necessary when track-laying was progressing rapidly. The cost of handling the plant was slightly over one cent per tie, and as nearly all the ties went to the front as fast as they were plated, this figure included the cost of loading. The actual cost for plating and loading 149,836 ties during the months of March, April and May was $1717.67, or 1.146 cents per tie. This was made up of labor 1.056 cents, fuel .075 cent and the balance, or .015 cent, was chargeable to repairs, oil, etc. The fuel was coal at $6 per ton of 2000 lbs. The number of men employed during this part of the work was one pressman, one foreman and 15 laborers. After plating ties in this way for a number of months the machine was removed from the car and placed on a platform in the material yard. All ties received here came from barges and were delivered directly to the machine, in slings, by a derrick. They were passed through the press and then placed on cars for piling in the yard or sending to the front, as was necessary. A 30-h. p. boiler was used, furnishing steam for the derrick as well as the press. When ties were shipped directly to the front, the cost per tie from barge to car came as low as 0.6 cent.

It was found that the plates remained in place during shipment to the front, and that during the distribution of the ties for track-laying but very few fell out. When this occurred a man, whose business it was to look after the tie plates, replaced them in the grooves which had been originally made. When the rails were strung out, the plates which came on joint ties were changed and the joint plates, which had a different punching, were substituted by the same man. The plates as they left the machine were spaced so that they were exactly in place for gage and line and, except for the joint plates, required no changing of position when placed in the track. The redwood ties used on the Pacific coast are what are known as "split ties," and there is a slight tendency for the grain to be in wind. It was thought at first that on this account it would be necessary to spot them, and such was done for awhile, but later on when it became necessary to rush the machine this practice was abandoned, and the results afterwards were so satisfactory that the spotting was not again resumed. It was found that the powerful work of the presses left the top surfaces of the plates practically in the same plane. Subsequently the same machine was used in plating ties for the construction of the San Pedro, Los Angeles & Salt Lake R. R.

On the Southern Pacific road tie plates on bridge ties have in some instances been driven to seat with a pile driver, before the ties were laid. The ties were placed under the 3000-lb. hammer, the plates set and the hammer dropped 2 to 3 ft. Use has also been made of a hand machine with a lever and cam arrangement for pressing the plates into the ties. Figure 275A shows a machine of this kind used on the Pacific Electric Ry., Los Angeles, Cal. It consists of two cams or eccentrics worked by levers, mounted on a large stick of timber. At the end of each lever there is a cast iron eccentric working loose on a shaft held by straps fastened to the sides of the timber foundation. Extending under both eccentrics there is a gage bar, on the under side of which there are two cast plates, each of which has two square lugs. These lugs fit into the spike holes in the tie plates, and the cast plates are at such a distance apart that tie plates fitted on the lugs stand to the proper gage for the rails. In order to lift the gage bar from the tie when the eccentric is thrown up it is attached to the latter by means

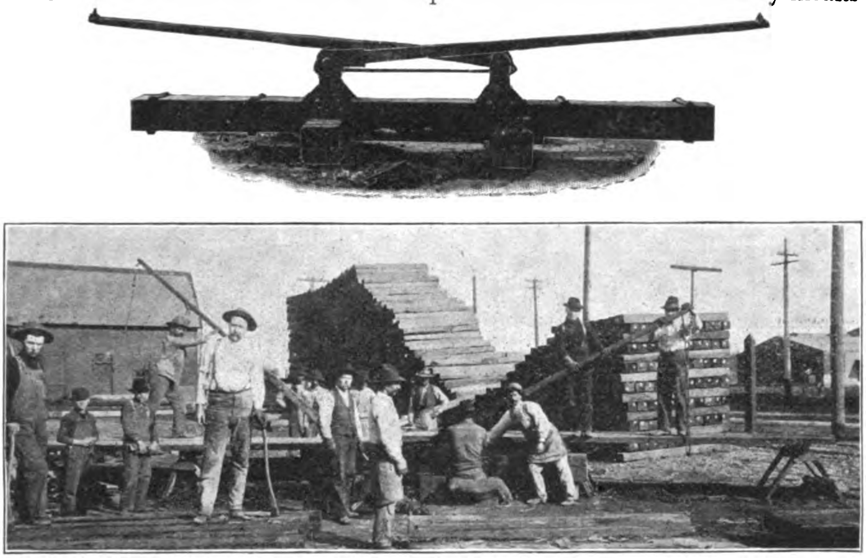


Fig. 275A—Lever Tie-Plating Machine, Pacific Electric Ry.

of a light chain. On either side of the two levers there are pipe rollers for entering and removing the ties, the roller nearest each eccentric being placed to act as a gage for the tie. In operating the machine, the ties are first adzed, to properly seat the plates, in case such is necessary, and then the ties are pushed over the rollers and under the eccentrics, one by one. The tie is pushed to butt against the gage roller, and a man at either end places a tie plate to fit the lugs on the gage bar, holding it in place with a small flat bar of iron. As the tie plate enters the tie, when the lever men throw over the levers, this bar is withdrawn. The levers are thrown entirely over toward the other end of the machine—that is, nearly 180 deg.—and the plates are pressed home. As fast as the plates are seated the ties are pulled out from the end of the machine opposite from that in which they entered and are carried to the plated tie pile. One machine with a crew of 16 men will plate 1000 ties in from eight to ten hours, according to the uniformity of the ties in respect to dimensions, wind in the faces, etc., at a cost of about 3 cents per tie.

Tie-Plating Old Track.—In applying tie plates to ties already in the track the first thing to do is to adz an even bearing for the plates on the rail-cut ties. Disregard of this important requirement usually results in

Fig. 276.—Laying Tie Plates by Method of Throwing Out Rail.

buckling of the plates. At one time a special tie plate of Goldie claw pattern was made for use on tangents, to be applied without adzing rail-cut ties. The length of this plate was approximately the width of the rail base, and there were no spike holes. Other advantages in contemplation were that it could be used with rails of any width of base sufficient to cover the plate; that it could not buckle or get out of shape under any conditions of service; that it would be cheaper than longer plates and that it would fully protect the tie from wear under the rail, which is the only place where wear takes place. Notwithstanding these expectations, the plate did not come into extensive service. Other matters requiring attention in setting plates on ties in the track are to plug the holes from which spikes have been drawn, and to drive the spikes perpendicularly through the plate, so as not to bind against the plate and prevent it from settling down to a firm and even bearing. In order to drive all of the spikes to take a firm bearing on the rail it is necessary to hold up some of the ties with a bar.

Methods of embedding tie plates on ties already in the track are quite numerous. Apparently the easiest, but in the end the most unsatisfactory, method is to draw the spikes, apply the plates loosely to the ties, redrive the spikes as far as they will go and then wait for the traffic to settle the plates into the timber before completing the job by driving the spikes to final depth. In some cases it takes considerable time for the plates to become seated, and meanwhile gravel, cinders or other dirt will get under the plate and cause it to take an uneven bearing. In view of this delayed action of the plates a plan that has been put into practice is to lay the plates only on every other tie or every third tie at one time and permit the trains to press them into the timber. In this way the weight of the traffic is concentrated on fewer plates and they are forced into the timber sooner than is the case where it is attempted to embed all the plates at the same time. The practice of embedding tie plates by train pressure has been styled the "automatic" method or the "lazy man's way," but it is the quickest way to get the plates into the track and has been very extensively employed. Until the plates become seated the aspect of things is displeasing, to say the least: the rail fastenings are in a slovenly, if not uncertain, condition, and the rails are liable to settle out of gage, particularly on curves and wherever the track is out of surface. It is needless to say that this method is not highly recommended.

The next general method which might be considered is that of setting the plates under the rail in place and pounding them down in some manner with a sledge hammer. By this method the track is not obstructed and the work can proceed without much regard to the trains. The spikes are pulled on a few ties at a time, and started on a few ties still further ahead, the rail is lifted high enough to slip the plates under, and the latter are driven down to place one at a time. The best plan is to place only one plate at a time, as then the full weight of the rail can bear upon it and be of material assistance to the driving force. The driving is frequently done with a sledge hammer and set, or with hammer and a thick plate or follower placed on the tie plate to protect it from being injured by the blow. In some instances two hammers are used, striking over diagonally opposite corners of the plate simultaneously. Sledges weighing 12 to 16 lbs. are best for this work, the preference being with the heavier weight. A heavy sledge is also convenient for knocking around ties that are out of square with the track. On the Norfolk & Western Ry. it has been the practice to embed one end of the plate at a time in the following manner: The rail is lifted and the ties properly adzed and the tie plates slipped under the rail. One end of the tie plate is then put down by means of a sledge or other driving tool, and then a wedge is slipped between that end of the tie plate and the rail base to hold it down while the other end is being driven. With the tie plate thus secured the other end is driven to a proper bearing. The "hammer-blow" action on the ends of the plate is not, however, always satisfactory, as tie plates have frequently been cracked or broken up by improper driving with sledge hammers and plates. The introduction of the "straddler" for driving tie plates with hammers has not been successful, as a tool of sufficient strength to endure the service was usually found to be so heavy as to absorb too much of the blow.

Another method of embedding tie plates, which is in considerable use in applying longitudinal flange plates to soft wood ties, is that of "plowing" them in. This is done by lifting the rail high enough to admit the end of the tie plate underneath it, and then to let the weight come upon the plate and drive it through with a spike hammer, the flanges plowing their way through the grain of the wood. The plate is driven from the gage side of the rail. With some trackmen it is the practice to start the plate by driving it under the rail without lifting the latter. This is done by placing a spike under the outer end of the plate and pounding down the end next the rail flange until it will make entrance under the rail when struck endwise. The objection to "plowing in" tie plates is that furrows are made in the tie face outside the tie plate, into which rain water will collect to start early decay, in the bruised fiber, and from which the water finds an easy entrance under the plate. In the early days of tie plates mention was sometimes made of the method of burning the plates into the ties. A fire would be built and the plates heated just hot enough to burn their way to a snug fit on the tie when pressed by the weight of the rail. Some professed to think that the charring of the wood under the plate had a preserving effect on the fiber, but for some reason or other the method has not survived.

It is easy to see that when tie plates are embedded with the rail in position, the latter is a serious obstruction to the work. It would seem, therefore, that matters should be much facilitated by having the rail entirely out of the way while the plates are being settled into the ties, and such is a method extensively followed. It obstructs the track, of course, and necessitates sending out flagmen, but in working a gang of considerable size it affords opportunity for the best speed. The spikes are pulled from a stretch of rail on one side of the track and the rail is thrown out of position far enough to leave the upper surface of the ties entirely clear for whatever adzing may be necessary and for the embedment of the plates, as shown in Fig. 276. The plates are set by gage and driven into the ties with a beetle or other striking tool. The use of the Ware gage is shown in this figure. After the ties have been adzed the surfacers are set to proper gage for placing the plates. In this application of the tool the fixed surfacer is made to abut against the web of the opposite rail, as shown. Each plate is located by placing it in the angle formed by the end of the adjustable surfacer and a projecting arm which shows clearly in Figs. 273 and 274. After all the plates have been embedded the rail is thrown inward and spiked to place. When using the Kiley tie-plate gage (Fig. 272) in work of this kind the hook is removed from the gage and the adjustable head *B* is loosened and turned half way around on the bar, or so that it stands upside down. With the rail on one side of the track moved out of its seat and the ties adzed off to give proper bearing for the plates, the gage head *A* is placed upon the top of the opposite rail, resting upon the lugs *C* and held in position by the clips *E*, which bear against the gage side of the rail. The other head of the gage is then brought down upon the tie right side up and the tie plate is placed in the rectangular space in the proper position for embedment. The gage used by Roadmaster J. W. McManama, of the

Fig. 277.—Tie Plate Driver, M. C. R. R.

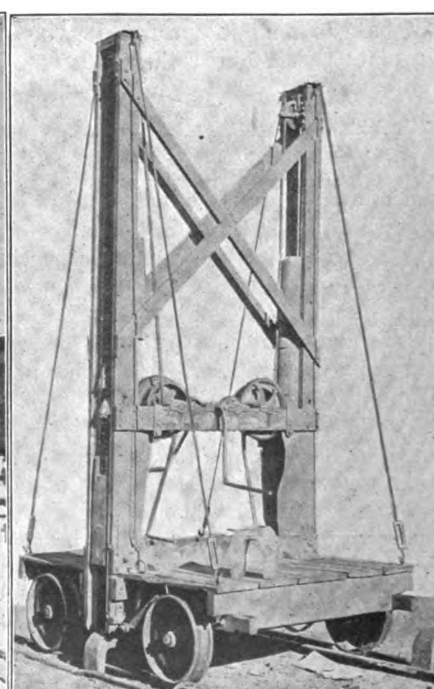


Fig. 278.—Tie Plate Driver, S. P. Co.

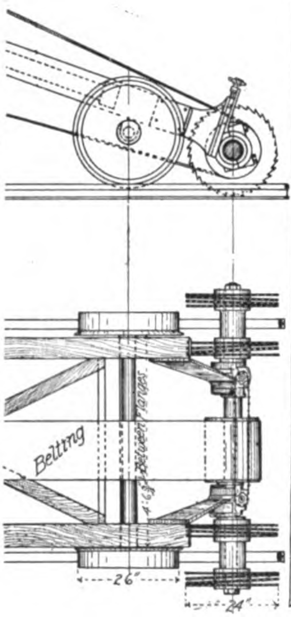
Boston & Maine R. R., for locating the exact position of tie plates with one of the rails moved out, consists of a piece of rail about 2½ ft. long riveted to the single end of a Huntington track gage, the forked end being retained for use against the rail opposite the one moved out of its seat.

For the most economical and most expeditious work of applying plates in this way, it has been found advisable to get as many spikes drawn as safety will allow, plug all spike holes and do all adzing possible before disturbing the rails. Then, when there is sufficient time between trains to permit such a move to be undertaken, all of the men are put to work with claw bars to draw the remaining spikes and move the rails out on the ends of the ties, as before described. The men are then organized three in a gang, one man to carry the gage and place the plates in the square; the other two men with wooden beetles to settle the plates into the ties. The first blow, as least, is given by a man standing at right angles with the longitudinal ribs of the tie plate, if such plates are being used; this in order to cause the plate to settle more accurately than would otherwise be the case. When a sufficient number of plates have been embedded to allow the rails to be moved back into position, one of the embedding gangs is turned back to move the rails in onto the plates and spike them; thus keeping the different parts of the work going at the same time, so that should an unexpected train arrive there would be but little delay in making the track passable.

In placing tie plates upon new switch ties the two plates for the main-track rails are applied before the ties are placed in the track, and the plates for the turnout rails are temporarily withheld until the main-track rails have been fully spiked and thrown into proper alignment, the turnout rails meanwhile being temporarily held by a sufficient number of spikes to permit the safe passage of trains. The plates are then applied to the turnout rails in the same manner as already described for applying plates to ties in track. Considerable use is made of long tie plates, which extend under both main and turnout lead rails, where they lie close together, plates as long as 24 ins. being sometimes used in such places and under frogs. In such plates it is usual to punch only two holes at the mill, these being near one end of the plate. When laying the plates they are first put under the lead rails, as aligned for their final position, to mark the position of the spikes, and then they are removed and punched by hand tools.

Machines for Tie-Plating Track.—With sufficient force to drive it, a follower made to straddle the rail and rest upon the projecting ends of the tie plate is a pretty satisfactory tool for embedding plates in the track. Such a tool is known as a "straddler," and on some roads machines built on the principle of a pile driver, on a small scale, are used to administer the driving force. One of these has been in service on the Michigan Central R. R., having been devised by Roadmaster M. Sullivan. This machine consists of a light pair of leads hinged to sills placed upon an ordinary push car and pivoted to swing to working position over either rail. The machine is shown in Fig. 277, and although the photograph was taken when the weather conditions were not especially favorable for laying tie plates, yet all the essential equipment is seen in position to do execution. The straddler is a forked piece of steel weighing 24 lbs. The hammer consists of a cast iron weight with a wide and thick wrought iron strap shrunk around it to fit the grooves in the leads and provide a striking face on the bottom. The weight of the hammer is 100 lbs. It is lifted by a small rope running over a pulley at the top of the leads and thence to another pulley at the foot of the leads, between the sills. In lifting the hammer the rope is pulled by a man standing directly in the rear, or in the position occupied by the man who appears in the picture. The plates are applied by pulling the spikes from a short stretch of rail both sides the track, lifting the rail and placing the plates in position and then following with the driver, which is swung alternately from side to side, into position over each plate, as the car advances. The machine is handled and worked by two men. When it is desired to remove it from the track, the leads are made to fall backwards on the hinges by disconnecting the braces which secure them in the upright position. The driver and push car are then lifted off the track separately.

A machine tie plate driver used on the Southern Pacific road is of heavier construction, consisting of a strongly built push car with driver leads erected permanently at both sides, as shown in Fig. 278. These leads are braced together, and upon a strut uniting the two there are two winches, one for each hammer. The hammer in this case is much heavier than that of the Michigan Central driver, and must weigh several hundred pounds. The straddler is also much heavier, as would be surmised from the view, one being seen over each rail and another appearing on the front end of the car; it weighs probably about 100 lbs. The method of driving is obvious from



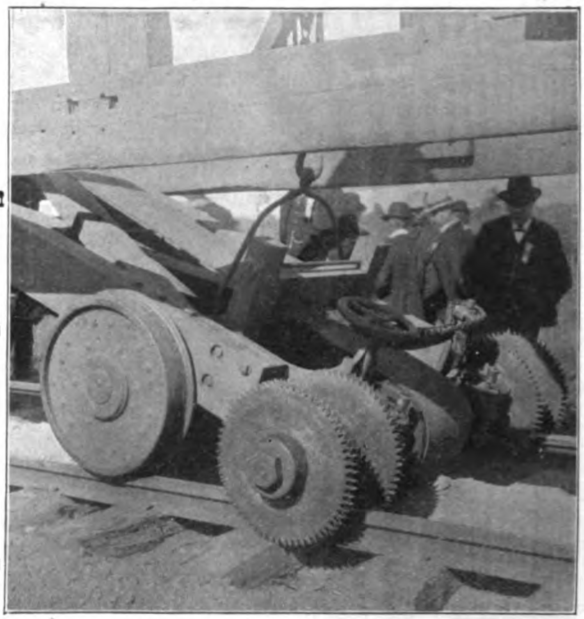


Fig. 279.—Wabble Saws of Brown Tie Spotting Machine—Fig. 280.

the picture. The plates are placed in position under the rail and the car advances, driving both plates on the same tie simultaneously. The hammer is raised by the winch and tripped by a foot lever operating a clutch which throws the winch out of gear. Each straddler used with this machine, when out of service, is lifted clear of the rail by a steel strap hanging from the side of the car, at points just over the wheels, and running under the bend of the straddler. As the car of which the photograph was taken was not in service at the time, being out of repair, this strap does not show on the side toward the observer, but it may be seen hanging down from the opposite side of the car, just ahead of the wheel. When it is desired to move the car ahead this strap is pulled up far enough to lift the straddler clear of the rail, and is then hitched to a peg. After the straddler is lowered to the service position, and while it is being used, the strap hangs loosely under the bend of the straddler. This machine was designed by the late J. T. Mahl, engineer of maintenance of way of the Atlantic division of the road, where several of the machines have been in service.

Reference has already been made to the practice of running ties through a "spotting" machine before they are laid in the track, to cut the rail seats parallel with the axis of the tie, and in the same plane, so as to afford an even bearing on the tie for the rails or for tie plates. An idea along this line has been worked out and put to practice to facilitate the cutting and evening of rail seats on ties as they lie in the track. The machine was conceived of and designed by Mr. George M. Brown, when chief engineer of the Flint & Pere Marquette R. R., which has since become part of the Pere Marquette R. R. system. The need of such a machine was suggested by a consideration of the following well-known facts: When rails become tilted or canted on curves the only remedy is to draw the spikes, adz the rail seats to a proper bearing and return the rail to a righted position. In placing tie plates on ties already in the track, a seat should be adzed for the plate wherever the tie has been cut into by the rail; otherwise, or if the plate is seated so that the ends are higher than the center, it will buckle. Again, when relaying rails with a new rail having a wider base

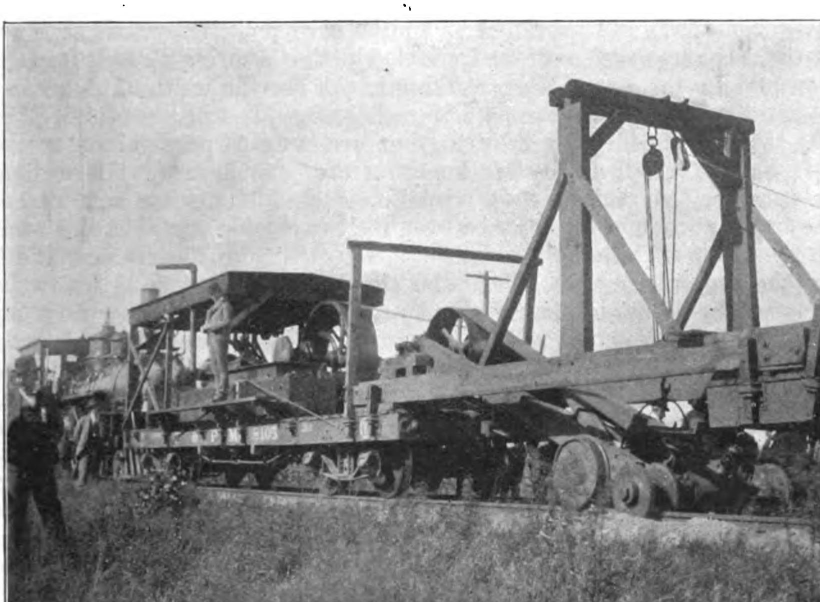


Fig. 281.—Brown Tie Spotting Machine, Pere Marquette R. R.

than the old one, a widened seat must be adzed for the new rail on every rail-cut tie. In such work the ties are usually covered with more or less sand and grit, so that the tools soon become dulled; and in any case, unless the men are expert with the use of the adz or are closely watched, the work will result in a saucer-shaped seat for the rail or tie plate, as the case may be.

The working portion of the machine consists in a number of circular saws, running in groups upon a common shaft, which is journaled in an arbor suspended crosswise the track and held in position to cut grooves each side each rail. The purpose is to cut a groove near to, and level with, the base of the rail, so that the trackmen will have a gage to work to when adzing the tie to an even seat for the rail or tie plate. Figures 279 and 280 show the lower end of the arbor and the saws, and Fig. 263 shows the work done by the same. To explain the source and transmission of the power, Fig. 281 shows a locomotive and train of two flat cars, the car next the engine mounting a stationary engine having a 12x20-in. cylinder and a

60-in. fly wheel, steam being taken from the locomotive through a hose connection. This engine drives a jack shaft on the head end of the car, from which a belt is run to the shaft bearing the saws, which is journaled at the end of an arbor swinging about the jack shaft. This arbor is supported at the track end by a pair of 26-in. wheels journaled about 30 ins. in rear of the shaft carrying the saws. Supported in this manner the arbor frame holds the saws in a fixed position relatively to the level of the rail and assures a uniform depth of cutting by the saws. When not at work or when passing switches, frogs, crossings, etc., the frame is swung upward from the track by block and tackle suspended from a bent supported upon beams extending between the two flat cars, which beams also maintain the proper interval between the cars. The tackle is operated by a winch on the head flat car. The saws are run at a speed of about 1500 revolutions per minute. Figure 280 is a near view showing the saws lowered into position for work.

In preparing for the work the ballast is removed to a depth of 2 or 3 ins. below the tops of the ties, in line with the grooves to be cut, and when in operation the train is moved forward (in the direction in which the locomotive is headed) at a speed of 4 or 5 miles per hour. The wheels supporting the arbor are gaged to fit the track closely, thus securing a steady forward movement for the saws. When working in oak ties the width of groove cut is 1⅛ ins. and three saws are used in each group. It will be noticed (Fig. 279) that the outside saws in each group are hung perpendicularly on the shaft, but the intermediate saws, known as the "wabble saws," take a diagonal position, so that in each revolution each intermediate saw sweeps over a wide portion of the space between the two outside saws. In this manner the group of saws cuts a groove corresponding to the extreme width over the two outside saws. For cedar ties the groove cut is 2¾ ins. wide. The saws are adjustable to cut a groove of any desired width and at any desired distance from the rail. The vertical adjustment of the shaft bearing the saws is effected by means of a screw, in iron brackets carrying the journals in guides, on either side, the two screws being operated together by means of sprocket wheels and chain. The saws when new are 24 ins. in diameter, but from wear and filing they gradually become smaller, the vertical adjustment of the shaft taking care of the diminishing diameter. The saws are also adjustable endwise on the shaft, so that the ties may be grooved in position convenient for the class of work on hand, whether it be renewing rails, changing gage, righting tilted rails or laying tie plates. If part of the ties are already laid with plates, as is frequently the case in old track where tie plates are gradually applied in connection with tie renewals, the saws are set far enough apart to miss the plates. An example of this kind is illustrated in the lower engraving in Fig. 263.

On the road where it was invented this machine has been very useful, as has been proven by the variety of work to which it has been put besides that of spotting ties for seating tie plates. In 1898 the Flint & Pere Marquette R. R. changed the gage of 92 miles of narrow-gage (3 ft.) track, and this machine was put to work cutting the seats for the rails, which were moved outward to the standard gage of 4 ft. 8½ ins. For this work six saws were arranged in a group on either end of the shaft and set to cut a seat 8 ins. wide. The inner edges of the grooves cut were 4 ft. 2¾ ins. apart, or in proper position for the rails to be moved to standard gage. With this preparation the stretch of 92 miles of narrow-gage track was changed to standard gage in one day, with a force averaging three men per mile. On some sections the work was completed in 12 hours and on others in 15 hours, on the day referred to. The actual length of track worked over that year was 110 miles, the remaining 18 miles of narrow-gage track being changed the following year. In one of the subsequent years the machine was used in cutting over 100 miles of standard-gage track in preparation for renewing rails.

Cost of Laying Tie Plates.—The cost of laying tie plates by hand on ties out of track averages about ½ cent each, and on ties in the track it ranges from ½ cent to 2 cents each, according to the kind of timber, the amount of adzing to be done, the extent of interference from trains, and, perhaps most of all, to the thoroughness with which the work is done; under ordinary conditions 1¼ to 1½ cents per plate is a fair estimate for good work. A maintenance of way officer who has paid much attention to tie plate laying for a number of years, requiring thorough work in all details, and who has kept careful records, gives 1.55 cents per plate as the average cost of the work of six different foremen, working 8 to 12 men in a gang, including flagmen. This figure includes time lost in going to and returning from work on hand car, the price for labor being $1.25 per day. The tie plates were of the Servis pattern, laid on oak ties, by the method of pulling the spikes and moving the rail out of its seat, using a Ware gage to set the plates, and beetles to drive them. The train movements were such that the track was opened each day for putting in plates an average of 4.43 times, and the average length of time the track was open in each instance was 39½ minutes. The actual cost of embedding the plates, not including any work incident thereto, was 0.14 cent per plate, which illustrates how largely the incidental items in thorough work of this kind figure in the total cost.

In order to carefully supervise the work of laying tie plates and be able to form correct estimates of the cost, or to draw comparisons of results under stated conditions, it is necessary to have itemized reports from the foremen in charge of the work. An example of such accounting, as made to the office of Mr. Henry Ware, roadmaster with the Buffalo, Rochester & Pittsburg Ry., appears below, together with certain explanations from that gentleman regarding his methods of work and records, which I think are interesting to publish. Mr. Ware states:

"My practice in putting tie plates on ties in the track is to 'double up' section gangs to assist the foreman on whose section the plates are to be put in, and the foreman in charge makes a daily report to me of work done, on a form for that purpose, a sample of which I submit herewith:

Daily Report of Tie Plates.

Put in on Sec. ....

Date....................190...

Curve No.	Track Opened.	Track Closed.	Why Closed.	No. Gages Used.	No. Beetles Used.	No. Men in Gang, Including Flagmen.	Kind of Ties.	No. Plates Embedded.	Trains Held.
15	9:05	9:35	End Curve	1	3	12	Oak	293	
15	10:30	10:50	Train	1	3	12	Oak	131	No. 45 not held.
15	2:33	2:50	Train	1	2	9	Oak	117	
15	4:23	5:25	End Curve	1	2	9	Oak	321	

John Doe, Foreman.

"As a rule I do not make a record of such reports, for it would require more clerical work than my office could devote to it. The distribution of labor at the end of each month covers it sufficiently for all practical purposes. My object in requiring such report is that I may know each day what the men are doing when I am not over the road to see them, and thereby keep in touch with what is going on. The knowledge that I am interested in each day's work acts, I believe, as an incentive to industry. As will be noticed on the form, I require foremen to report whenever they have been obliged to flag a train, giving the reason, and the length of time the train is held. A record is made of this report in my office. The object of this report is two-fold: first, that I may know if any unnecessary flagging is done; and second, to check up any exaggerated statement that may be made by the transportation department."

107. Bank Edging.—Deficiencies of construction, the washing effect of rains and the wasting effect of grubbing vegetation frequently leave the shoulders of roadbed on embankments too narrow or too much worn down to properly retain the ballast. In order to economically maintain the track surface it then becomes necessary to widen out the top of the embankment to full roadbed width or bring it up to sub-grade by replenishing the sunken

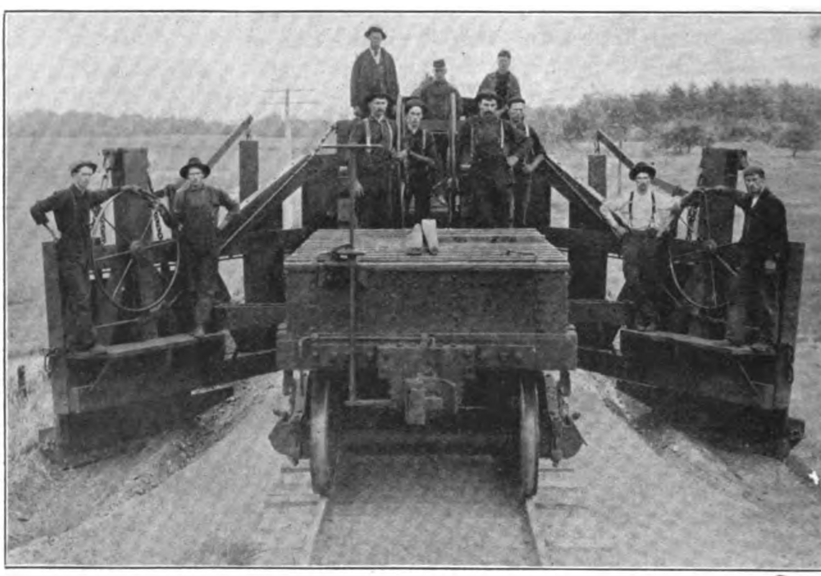


Fig. 282.—Track Shouldering Car, Boston & Maine R. R.

shoulders, especially if the ballast is to be renewed or the track raised to a higher grade line. Such work is known among trackmen as "bank edging." The filling material necessary for this purpose may be obtained and deposited in various ways, one good plan being to so dispose of the earth that is removed from time to time in ditching cuts. On some roads, even on high embankments, such work is done with teams and scrapers, and in cases it is moved from the side of the right of way in wheelbarrows, but in perhaps the majority of cases the material is loaded with a steam shovel and hauled out by work trains. The work of leveling down the material that is dumped or plowed from cars and left in heaps along the track is an item of considerable expense, if done by hand, and in many cases where extensive operations of this kind have been undertaken machines have been designed for the purpose. Bank-leveling or earth-spreading machinery operated as an attachment to the side of a car is now commonly in service, both for shouldering embankments and plowing out filling material in grading for a second track. The principal difference in the construction of the machines for these two classes of work is in the sweeping distance or reach of the side wings or plows, although in some instances the adjustment of these parts is made sufficiently flexible to answer both purposes. The machines described in the present connection were designed primarily as shouldering cars. Other machines sometimes used for shouldering service receive mention in connection with "Constructing Double Track" (§ 112, Chap. VIII).

A track shouldering car that has been used satisfactorily on the Boston & Maine R. R. is shown in Fig. 282, as it appears in operation. It consists of a specially constructed 70,000 lbs. capacity flat car 34 ft. long, fitted with side wings carrying interchangeable knives. The width of the car over side sills is 6 ft. 4 ins. The wings, which are constructed of heavy timbers strongly framed together, are hinged to upright posts fixed to the side sills, at either side of the car, and securely braced both crosswise the car and longitudinally. The position of the wings, which can be extended or contracted, is controlled by sliding struts guided within a boxed way suspended from the middle portion of the car, and forced in or out by the large hand wheels and chains appearing in the center of the picture. The cutter knives, carried at the bottoms of the wings, each consisting of a ¾-in. x16-in. steel plate reinforced by a 4x4-in. angle and 3x6-in. channel, may be raised or lowered by racks and pinions operated by the hand wheels shown. Two men are required to adjust the cutter on each wing. At either end of the car are ballast boxes, in which scrap iron is placed to hold the car down to its work. Minor improvements made since the photograph was taken include a derrick, similar to the davits on a vessel, for handling the cutters from the wings to the deck of the car and vice versa, and an additional strut placed against the end of each wing when it is spread out to maximum distance.

This machine has been used both for shouldering down widened embankments and for leveling material to sub-grade for a parallel track. By extending the wings to their full sweep and attaching a special cutter for leveling purposes, material can be plowed out to a width of 12 ft. from the rail and to any desired depth not exceeding 18 ins. In shouldering work all surplus material can be removed from one or both sides of the track and cut to lines parallel with the rail, whether on straight or curved track, thus working the roadbed down to a uniform section of any desired shape. The machine can also be used for ditching. The force required to operate it properly consists of a train crew, a foreman and four men. As an example of what the machine can accomplish in comparison with hand labor, it is stated that the car in four days trimmed up a 30-mile section of track, the work on which if done by hand would have cost, as determined by actual trial, $75 per mile. The expense of the shouldering car outfit for the four days was $114.20, to which should be added $378, the wages of 70 men employed in leveling back material which the car could not reach, and clearing up material in cuts that the car could not dispose of. In one instance the car moved 500 cu. yds. of filling material, leveling it 6 ins below top of ties and 10 ft. from rail, over a distance of 1000 ft., in 25 minutes.

The Gulf, Colorado & Santa Fe and the Atchison, Topeka & Santa Fe roads have spreader and shouldering cars of a pattern shown in Fig. 283, built for spreading material plowed from flat cars to raise embankments in grade reduction, and to prepare the shoulders of embankments to receive the ballast. The design was worked out by Mr. E. McCann, supervisor of bridges and buildings for the Atchison, Topeka & Santa Fe Ry. The machine consists of spreader wings fitted to an ordinary flat car and provided with overhead hoisting apparatus. The wings are of ordinary heavy ($4\frac{1}{2}$-in.) plank construction, faced with boiler plate and hinged to the car at the floor line by means of heavy struts ironed off and well braced longitudinally with angle irons. Each wing is divided into two sections, the rear section extending from the ends of the ties outward, and the forward section from the rail to the ends of the ties and overlapping the rear section. The intention of the forward section is, of course, to clear away material from the rail and uncover the ties, while the rear section cuts to a depth even with the bottoms of the ties, or below if desired. The spread of the

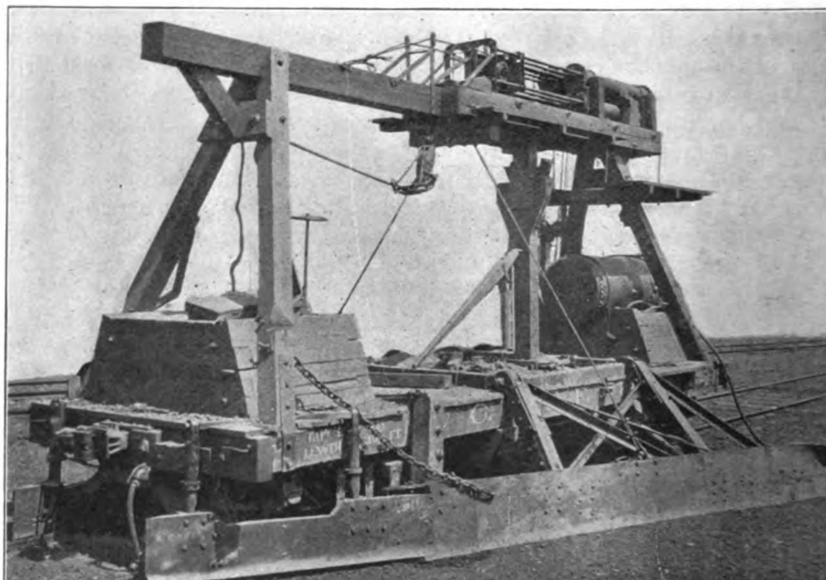
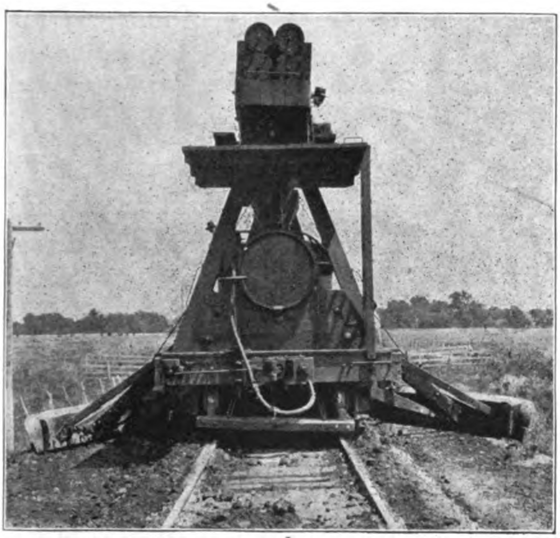


Fig. 283.—Track Shouldering and Spreader Car, G., C. & S. F. Ry.

wings is 13 ft. 8 ins. on each side of the center of the track. The front section is hinged to a heavy bar extending diagonally across the corner of the car, and a piece of stout chain is attached to the rear section to prevent dislodgment of the same in case a hinge should break. The side pressure against the front section is received by a hinged strut, which abuts against a stop block bolted to the under side of the end sill of the car. The side thrust against the rear section of the wing is received by struts abutting against heavy timbers extending across the car, underneath the sills. In constructing these cars a heavy timber box was placed at either end, with the idea that ballast might be needed to hold the car to the track while in service. In practice, however, it has been found that ballast loading is not needed, and the boxes are used as a place for storing chains, templet plates, tools, etc. The construction of the wings, leaning as they do from a vertical position, and sprung at the lower edge, and backed by struts hinged from above, is such as to give them a downward draft when plowing through material, the action being similar to that of a plow point. This draft assists in holding the car down to its work. The apparatus for hoisting the wings consists of four 8-in. air cylinders mounted upon a longitudinal beam that is supported upon an A-frame at each end of the car, at a hight sufficient to clear the wings in their raised position. These cylinders operate pistons which have a travel of about 5 ft., and the piston rods are fitted to a cross head to which are attached two pulleys, around each of which is doubled a wire cable for hoisting the wing on one side of the car. The pistons thus pull the end of the cable a distance equal to twice the travel of the piston. The weight of all the apparatus which is attached to the naked flat car is 22,600 lbs., of which 10,400 lbs. are carried by the forward truck, and 12,200 lbs. on the rear truck.

The wings are operated by one man, who stands at the end of the car, next to the air storage reservoir, where he handles the air cocks of the hoisting cylinders and where he can push the leveler arms over the dead center when lowering them to position. The air for operating the hoisting cylinders is taken from the brake system of the train. The cable for lifting the wing on each side is attached to the rear section, which lifts the forward



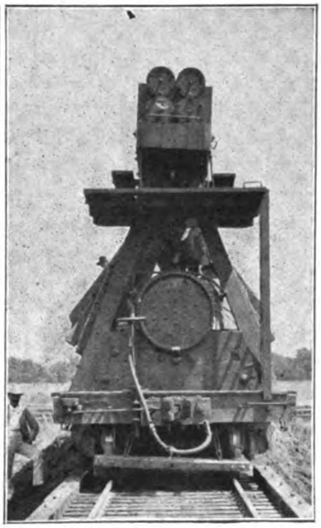


Fig. 284.—G., C. & S. F. Shouldering and Spreader Car—Fig. 285.

section, which comes to rest in a notch in the corner of one of the posts of the A-frame. In lifting the wings they are revolved past the center and thus rest in stable equilibrium. In lowering the wings to position they are shoved over the center by means of a lever shown, and dropped to working position by gravity, being controlled in their fall by admitting air to the cylinders, to act as a cushion. The wings can be raised to clear bridge floors, cattle guards, etc., in a very few seconds, and let down again into working position without requiring the train to stop. As a precaution against any failure of the air supply a rope tackle is carried on the framework for hoisting the wings in case of necessity. The air contained in the storage reservoir (capacity $57\frac{1}{2}$ cu. ft.) is sufficient for four applications. The pipes which feed the top cylinders are only $\frac{1}{2}$ in. in diameter, so that the flow of air is not sufficiently rapid to do damage to the machinery in case an inexperienced operator should open the cocks too suddenly. The wings when free from dirt are lifted without admitting full reservoir pressure, the cylinders being designed with a capacity sufficient to lift the wings when plowing through dirt the full depth, and when the train is in motion. There is an automatic valve to prevent the reservoir from being emptied in case the train should pull apart and break the hose connection. An end view of the machine with wings raised to clear is shown in Fig. 285, and Fig. 284 is an end view of the machine at work. For trimming the edge of the bank to form a shoulder a boiler-plate templet is attached at the outer part of the wing. This attachment is adjustable and can be set to trim the edges of banks 16 to 20 ft. in width.

Some minor improvements have been introduced on machines of later design which do not appear in these views. To prevent the end of the front section of the wing from scraping against the rail, and to carry it safely over rail braces and joint splices, a wheel has been placed at the front end to run on the rail and hold the wing to a proper clearance. On the cars of later design there are two hoisting cylinders (instead of four) each 14 ins. in diam. and 6½ ft. long, with a piston travel of 6 ft., and in putting the wings into service they are pushed outward past the vertical position by two 7-in. air cylinders—one for each wing.

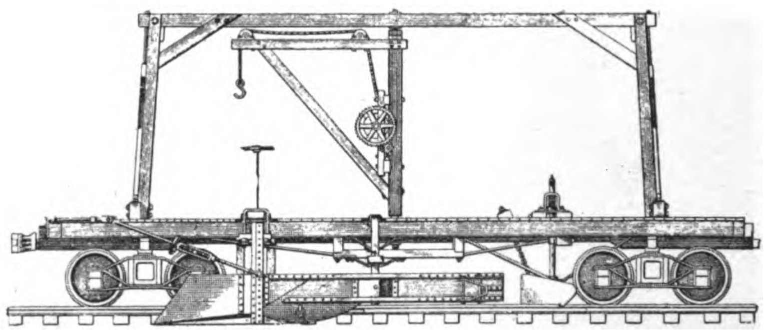


Fig. 285 A.—Side Elevation of Scott Ballasting Car, G., C. & S. F. Ry.

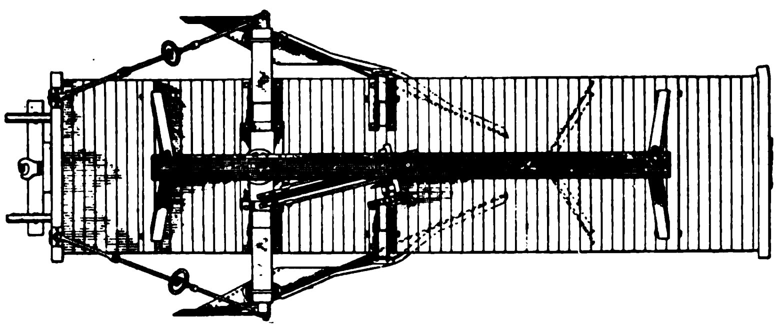


Fig. 285 B.—Plan of Scott Ballasting Car, G., C. & S. F. Ry.

In actual service this car has spread earth at the rate of 17,000 cu. yds. per hour, all the operations of the car being handled by one man. In one instance the car, starting from a standstill, dropped the wings and spread 176 car-loads of earth, carrying from 20 to 30 yds. to the car, in 13 minutes. Either one or both sides of the car may be used as desired. The stability of the car when spreading from one side only is sufficient for heavy work. In numerous instances two engines have been used to pull the car when it was spreading on only one side. So long as there is sufficient tractive force the car will plow its way through heavy gumbo or rock without difficulty. In leveling down rock large stones weighing from one to two tons have been handled without trouble.

A machine designed by Mr. W. R. Scott, while superintendent of the Northern division of the G., C. & S. F. Ry., is used to pull material inward to fill the center of the track. In one instance it was used in spreading the top material where a long trestle was filled in, taking dirt that was plowed from cars to the side of the track and filling in between the stringers, as high as the tops of the ties, thus dispensing with all hand shoveling. Besides filling in between the stringers it left the shoulder in proper shape. Another purpose of the machine is to handle ballast from the shoulder to the center of track that is to be raised for ballasting, thus dispensing with hand labor to this extent and with center-dump cars. The machine consists essentially of two winged plows hinged at the side sills of an ordinary flat car, with a crane for hoisting the plows to clear road crossings, wing fences at cattle guards, etc. Figure 285A is a general elevation view showing the position of the wing plows as set for service, and Fig. 285B is a plan view showing the position of the wings relatively to the track. The spread of the wings is controlled by chains winding upon a vertical shaft, with a brake wheel, and also by adjustable stay rods. The wings converge without meeting, and in rear of them there is a center plow for clearing the rails. The plows are made adjustable to varying widths and depths, so that if a large quantity of ballast has been unloaded they can be spread far enough to take in the extreme width. If it is desirable to make two lifts of the track in ballasting, the plows can be dropped low enough to bring the ballast up after one raise has been made. The ballast is left in exactly the same shape as though dumped from a regular center-dumping car and then plowed level with the rail and spread out over the ends of the ties. There is no danger of the machine clogging, as all surplus material is carried to the shoulder at the ends of the ties. It can be handled in this way at a speed of five or six miles per hour, and it has been used with equal satisfaction in gravel, crushed stone and slag ballast.

A side leveler and shouldering machine that has been used on the Kansas City Southern Ry. is built on a flat car, with wings of heavy plank hinged to upright posts framed over the side sills. The wings, which have a spread of 16 ft. on either side of the center of the track, are raised or lowered by compressed air supplied by the air-brake system, and when opened for duty each is backed by two brace struts. The swinging ends of the wings are supported by chains run to the tops of the posts to which they are hinged. The car is ballasted with three round wooden tanks, each holding 1800 gals. of water, which may be utilized to feed the locomotive in case the supply in the tender runs short, thus saving time which might be lost in making special trips to water stations. The total weight of the car with the tanks full of water is 48 tons. The wings proper extend from the ends of the ties outward. The tops of the ties are cleared by a flanger attachment held to its work by springs which permit it to yield when meeting the end of a high tie or other obstruction. The rounding of the shoulder over the top of the slope is accomplished by an adjustable plate attachment which drops below the bottom edge of the wing proper. On the Intercolonial Ry. the wings of a snow plow have been fitted with adjustable steel blades, to adapt it to the purpose of a shouldering car.

CHAPTER VIII.

DOUBLE-TRACKING.

108. General Considerations.—The report of the Interstate Commerce Commission for the year ending June 30, 1902, puts the aggregate length of railway line in the United States at 202,472 miles. This total mileage was made up of 188,751 miles of single-track road, 12,517 miles of double-track road, 309 miles of three-track road and 895 miles of four-track road (there being 13,721 miles of second track, 1204 miles of third track and 895 miles of fourth track), so that 93.2 per cent of all railway line was single track. In 1890 this percentage was 94.8, the average decrease being about one tenth of one per cent each year. Any general treatment of track therefore applies principally to single track. So much of the work of construction and maintenance considered in the foregoing chapters has the same application to double that it has to single, track, and so many variations of methods specially applicable to double track have been pointed out, that but little additional need be said with special reference to double track. There have not been opportunities, however, to go into certain details of double-track construction and operation, and these may perhaps be best treated in a separate chapter.

109. Advantages, Etc.—The advantages to be had with double track, over single track, are many, not a few of which must be apparent from the standpoint of the trackman, as well as from that of men engaged in the transportation department. Of course the advantage most likely to be considered is that of profit, and usually the question which must determine the advisability of double-tracking a road, or any part of it, is whether the additional traffic which can be had by increasing the capacity and facilities of the road, will increase the receipts sufficiently to warrant the expense of additional construction and maintenance; or, perhaps, indeed, whether the traffic already at hand could not actually be handled on double track with increased economy sufficient to compensate for such additional outlay. It is no doubt true that as the traffic on a road increases, the point where the same traffic can be handled more economically on double, than on single, track will be reached before the single track becomes crowded to the full extent of its physical possibilities. The chief consideration which settles this principle is the obvious fact that the trains can be moved with greater convenience, dispatch and safety, and hence with increased economy, on the double track. The element of increased safety obtains, for the most part, from the fact that on double track less dependence is necessarily placed on human reliability and foresight. Nevertheless, with double track it is possible to eliminate from the track itself many features properly considered elements of danger in train operation. A discussion of the question "Limit of Capacity of Single Track" is published as § 207, Supplementary Notes.

On double track there is but little passing of trains which use the same track, and hence sidings or passing tracks can to a large extent be dispensed with, so that danger inhering with frogs and switches is far less. This is true, not necessarily because the dispensing with so many sidings makes frogs and switches less numerous, because for every siding taken out there will usually be put in a crossover, which double track operation requires at most stations; but such crossovers can be laid with frogs and split switches trailing to the prevailing movement of the trains, so that the danger arising from such appliances when used on single track is removed. Likewise, double track naturally favors making the switches for all, or nearly all, spur tracks, trailing switches; whereas, in making a round trip with a train over a single-track road or division, every switch on the line becomes a facing switch to that train once during the trip. Also, on double track the total number of switches is divided between two tracks, so that a train in going over the road in one direction does not pass over all the switches and frogs on main track, as it necessarily must on single track.

110. Comparative Cost of Construction and Maintenance.—The first cost for rails, ties, fastenings and ballast for double track is twice that for single track, but the same ratio does not hold true in other particulars—it favors always the double track. Thus, for instance, in earthwork with slopes 1½ to 1, a roadway 18 ft. wide, in cuts or fills of 10 ft. depth, may be widened out to 31 ft. (the corresponding width of roadbed for double tracks at 13 ft. centers) by the handling of only about 40 per cent more material, the proportion of additional material growing less as the depth of cut or fill increases. The same ratio will hold true for the increased cost of masonry for bridge abutments for double-track, as compared with single-track, structures. In most regions cuts and fills of the above dimensions are only ordinary with roads handling a traffic so large that they can afford to double their tracks. And besides, the cost for filling or excavating per yard of material for an additional track should be less than that for a single track, after the single track is once in operation, owing to the increased facilities for hauling, handling by machinery, etc. Taken all around, therefore, the cost for earthwork for a second track should usually not exceed 50 per cent of that for a single track on the same location. As regards cost of construction of a second track, it ought to be considerably less than the cost of the first one, since the materials can be distributed much more cheaply; moreover, better opportunities are offered for the company to build its own track, and not only save the profit which ordinarily goes to contractors, but to build it as it should be built—which contractors not always do.

In the matter of repairs or maintenance expense, approximately twice as much will be required for tie renewals for the two tracks as for one. Where trains run frequently rails lose but very little from rust, so that the cost of renewing rails for double track will not much exceed the cost of renewing the rails for the same length of single track carrying the same traffic. There is also much work, such as ditching, mowing grass and weeds, cutting brush, policing, repairing and renewing fence, track-walking, bank-edging, maintaining snow fence, protecting banks, and other work which requires the same time for single as for double, track; in fact, the cost of mowing and cutting brush on double track is sometimes less than it would be on single track for the same width of right of way, owing to the narrower width outside the slopes at cuts and fills. Regarding lining and surfacing, the cost for two tracks will not be twice that for one, because each track undergoes only half the service which one track would in carrying all the traffic. Unlike the matter of rail wear, however, the work of maintaining two tracks in line and surface is more than that of maintaining one track to carry all the traffic, for the impairment resulting from weather conditions, such as rain and frost, may reasonably be supposed greater on double track than on the same length of single track, not only because of the greater extent of track structure and roadbed, but also because double track is not usually as well drained at sub-grade as is single track. Data bearing on this point would seem to indicate that the cost of raising and tamping double track to hold it in surface is 40 to 70 per cent greater than the cost of performing like labor on the same length of single track to carry the same traffic tonnage. In another respect, however, double track is favorable to lower cost of surfacing than it might otherwise be, as there is less interruption to the work, for the same number of train movements, and the trains are more likely to run on the regular schedule, so that track work can be laid out to better satisfaction. Consider, as an instance, the case of two freight trains, each consisting of three or four sections, scheduled to pass at a certain point on single track. If one or two of them should be just enough behind time to cause the meeting point to be changed from the regular one, trains might become so strung out as to seriously hamper the work of several section crews for the large part of a half day—not to speak of the worry over the work which such an interruption sometimes brings upon the ambitious foreman, often resulting in irritation and eruption between him and his crew—etc., etc. As experienced trackmen know, this matter of delayed trains cuts considerable of a figure in the progress of track work. It is not at all a question of time lost while workmen stand aside for trains to pass, but the uncertainty regarding the time the trains will be along, which often catch the work when it is partly done, requiring it to be performed the second time or, in many instances, causing delay as a matter of precaution, in starting out with the work. Taking all matters into consideration, it is a reasonable estimate that the cost of keeping up two tracks on the same roadbed to carry a stated amount of traffic does not exceed that necessary to maintain one track to carry the same traffic, by more than 45 to 55 per cent. As the result of a careful study of this question, using average cost data covering the various items of the labor and material accounts of track maintenance, I find the ratio of the expense of maintaining single track to that of maintaining double track carrying an equivalent tonnage, to be 1 to 1.52. In this calculation interest charges were not taken into account.

111. Preparation for Double Track.—In this country, where so much of industrial development has depended upon the railroads, the history of roads which operate two or more tracks has been in nearly every case the building at first of one track, with such limits on grades and curvature as the outlay—which the apparent traffic of the more immediate future seemed to justify—would permit. As commerce and travel to and from the districts tapped by the roads have increased, the roads have usually reduced the grades (where the same have been of an undulating nature), eased or taken out curvature in places, and gradually brought the line into better condition; after which double-tracking has been accomplished as increased traffic, competition and other matters have demanded. Good examples of such development are the New York Central & Hudson River and the Pennsylvania roads. The New York Central has on its main line four tracks—two for passenger and two for freight trains. The Pennsylvania road also has four tracks on its main line.

Wherever there is the least likelihood that double track will ever be needed, the plans for it should be constantly in the view of the management from the time the road starts, even though nothing toward it can be done at first. Such matters as looking out for plenty of room while obtaining right of way in the vicinity of locations where expansion seems probable, or such locations as seem liable to be changed eventually, are well worth consideration, and it can usually be had without additional expenditure if negotiated for before the road is built. Sidings built from time to time should, as far as practicable, be laid out to conform to the main line roadway in grades, and at standard distance from it, where the location is good; otherwise they should be located with a view to bettering the location of main line should it seem likely that at any time in the future it will form part of a second main track. In this connection, too, even without having double track in view at all, it is good engineering, when laying out a siding or spur, if it can be accomplished without too much inconvenience in other ways, or without too much cost, to locate it at some point where the curvature of the main line needs improvement. By building a piece of track on the new location and throwing the main line to connect with it at both ends, the old piece may be used for the side-track, simply by putting in a switch—and changing the rails, if it is desired to make use of an inferior quality of rails for side-tracks. The matter of lap sidings as favorable to the subsequent building of double track, is touched upon in a previous chapter. By giving the proper amount of attention to such things during the progress of constructing and developing the road, double-tracking becomes an easy matter, comparatively, when it has finally to be done, and at the same time improvements on the general alignment of the old line can gradually be brought about. It is frequently the practice when putting in permanent bridge piers and abutments to make them of such dimensions that they may answer later for double-track structures. The cost for additional masonry required is comparatively slight in work of any considerable hight. In the matter of superstructure, however, Wellington points out that a double-track bridge weighs 90 per cent more than a single-track bridge designed for a corresponding loading, and he concludes, therefore, that it is not good policy to arrange for a third truss unless double track is certain to be built within a year or two.

Double-tracking is usually begun on that part or parts of the road where the local traffic is most congested, other considerations not interfering, and extended by sections at a time until finally it reaches the whole length. Thus parts of a road may for years be double and other parts single, track. The meeting of the second track with the first is designated "end of double track," at which point proper signals are maintained and a switchman is stationed to look after switching the trains. The switch at end of double track should be a point switch, placed preferably on straight line, where approaching trainmen can see the signals clearly for a good distance from either direction. The frog should be of large number, thus giving a lead of easy curvature, and making it possible to run trains through it at fair speed. No. 12 frogs, corresponding to a lead curve of 4 deg., are sometimes used at such places, and No. 14 to No. 18 frogs quite commonly, while in a few instances frogs as high as No. 24 have been used. To cite an example of the use of a frog of the number last named, there was for some years at the end of double track on the Cleveland & Pittsburg division of the Pennsylvania Lines West, at Bedford, O., a No. 24 rigid frog 30 ft. long, 19 ft. from point to heel, constructed in the ordinary manner. It was used with a 30-ft. split switch, having a spread of 7 ins. at the heel, and with 30-ft. guard rails, in a turnout of practically 1 deg. curvature (theoretical radius being 5472 ft.). The frog had to be renewed about once each year, and is said to have given excellent satisfaction.

112. Constructing Double Track.—The work of excavating and filling for a second track can usually be done most economically with steam shovel and work train. The shovel or excavator is used to widen the cuts and the material is hauled to widen the fills. Unless the cut, in any case, is long or deep it is not worth while to lay a turnout to get the shovel off the main line. The way this is usually done is to remove the ballast from between the ties and then cut the track and throw it over to connect with an isolated track running into the face of the cut; run in the shovel and its tender, throw the track back to place and couple up. With a work-train crew the change can be made in a short time. The piece of isolated track should be started right to make joints with the piece of main track thrown over. It is not necessary, however, to throw the main track ties at all, but to simply pull the spikes from a rail each side of the track, cut the rails loose at one end and throw the free ends over slightly on the ties so as to lead from the main line. Beginning with these rails, a temporary turnout may be laid to be continued as the isolated track, blocking under the off rail as far as the near rail remains on the old ties, running a tie under the off rail and main-track rail occasionally to hold the former to gage with its mate, which is spiked on the old ties. Instead of using a frog, the main-track rail may be taken up where the turnout rail crosses that side of the track. The tender car or tank for the shovel may be supplied with water by hose from the locomotive tender or from a water car standing on main track. The work train must, in any case, stand on main track while loading; and, as far as possible, it should be arranged to unload while on the way to a passing track to clear for regular trains or upon the return therefrom. If, however, the work in the cut will require the use of the shovel for a considerable length of time, as in a deep bank, it will pay to lay a turnout for switching water and fuel cars to the shovel. In the case of a long cut the track behind the shovel may, after some progress has been made, be used by the work train

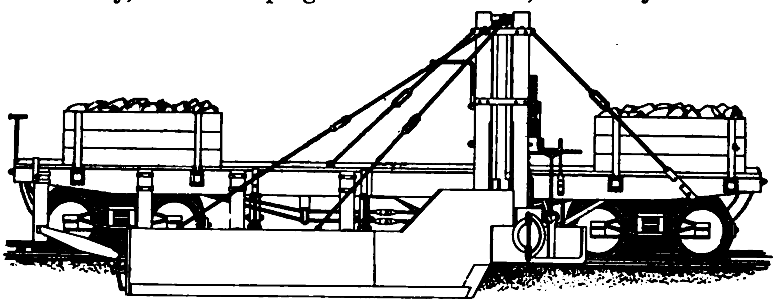


Fig. 286.—Jordan Spreader Car, Michigan Central R. R.

to let the regular trains pass. The shovel should work its own way through the cut. It should have a derrick of such length that it can stand clear of main track, reach far enough into the bank to cut the required width of roadway, and still reach the cars on main track. After the work at the cut has been completed the shovel may be taken onto main track in the same manner that it was taken off, and then proceed to the next cut.

In transporting material from long cuts to adjacent fills, surface-hauling tram roads with dump-cars are sometimes employed, the system being applicable to either grade reduction or to double-tracking. In the work of reducing grades on the main line of the St. Louis, Iron Mountain & Southern Ry., it was found necessary in some cases to transport material from a summit where the cut was made, for a distance of a mile or more, to the point where the material was deposited in the fill. Instead of using a steam shovel and work train a surface tram road was laid on each side of the main line, using a mine hoisting engine driving an endless cable, which hauled the train of dump cars from the cut to the fill, and vice versa.

In filling for a second track close by the main track the material is most cheaply unloaded by side-dump cars or by plowing it off the cars with an unloader. The usual arrangement is then to work the material over with teams, using side-hill or railroad plows, with reversible mold-board for furrowing either way. A small force of men is required to keep main track cleared and to trim the slope. On roads where considerable double-tracking is to be done, a spreader or grading car is frequently used for plowing the material off the shoulder. One of the earliest cars of this kind was used on the Michigan Central R. R., where four of these machines were built on plans devised by Roadmaster O. F. Jordan. The car is narrower than common, being only 6 ft. 11 ins. wide over the side sills. On each side of the car, and braced together across the car, are erected two 8x9-in. posts with an 8x10½-in. post sliding between them, the latter being raised or lowered by racks and gears (Fig. 286). The sliding post carries a wing or side leveler which is 22½ ft. long, made of heavy plank and faced with boiler plate. The bottom or scraping edge of the wing is reinforced with an iron strip ¾ in. thick. At a point just beyond the ends of the ties the wing has a downward offset of 22 ins. The vertical limits within reach of the scraping edge of the wing are 22 ins. below top of rail and 10 ins. above the same. The wing is braced to the side of the car by three struts, of which there are two sets of different lengths for holding the wings at different angles. With the wing set at the extreme angle it sweeps 15 ft. 4 ins. from the side of the car, although one car of this pattern built for the Michigan Central R. R. is 40 ft. long and has wings that sweep 20 ft. from the side of the car. The machine is operated by two men, who can raise or lower the wings at will. The manipulation of the car in spreading earth is about as follows: The spreader car is coupled in just ahead of the way car, and while the earth is being unloaded two of the train men extend one or both of the wings, as the case may require, and lower them to the desired level. As soon as the earth has been unloaded from the cars the engineer is signaled ahead and the material is spread uniformily as far out as the wing is set. The car is held down to its work by weighting it heavily with rock, in ballast boxes at either end.

Aside from the work of spreading earth dumped as filling material in double-tracking, building side-tracks, or widening embankments, the car can be used for a variety of purposes. One use to which it readily adapts itself is the spreading of ballast on new grade. After the roadbed has been prepared the required amount of ballast is unloaded on the grade, before the track is laid, and then it is spread with the car in the same manner as when spreading earth. After the track is laid ballast is again unloaded by the side of the new track and spread over the same with the wing resting on top of the rails of the new track. The car can also be used for removing snow piled up at the side of a track or between tracks, as in yards. This is done by extending the wing to reach over the outer rail of the parallel track, and then the wing is lowered to slide upon the rails. The train may then be moved at good speed, the car at the same time throwing the snow from between the tracks to a distance corresponding to the sweep of the wing. In removing snow from yard tracks the material is thrown from track to track successively until entirely outside of the yard. For sloping the shoulders at the side of the track a special sloping blade is substituted for the wing and attached to the upright post, and handled in the same manner as when spreading earth or removing snow. For ditching, one of the wings is removed and a scraper and earth carrier is attached to the upright post and handled in the same manner as when spreading earth. In ditching, the car will work both ways, delivering the earth at either end of the cut. When the car is not in use the wings are raised and folded against the sides, when the car can be coupled into any regular freight train and transported to desired points. Cars of the same design have been used also on the Southern Pacific, Illinois Central, Grand Trunk Western and other roads.

The Duluth & Iron Range R. R. has a spreader car designed on the same general lines as the Jordan but different in some details. The wings or side levelers are hinged to 9x9½-in. oak posts sliding between upright guide posts attached to the side of the car, and are raised and lowered by means of gearing operated by hand cranks, as with the Jordan design, but to avoid building a narrow car, so that when the wings are folded against the side of the car they come within the clearing limits, this requirement is provided for by cutting away the side sill and setting the hinge post and guide posts in flush with the side of the car. Then, in order to strengthen the floor, which is necessarily weakened by cutting the side sill, a 6x8-in. beam is laid longitudinally on the deck on each side of the car, just in rear of the hinged post, and bolted down through a sill with long bolts. Another feature of the mechanism which is a little different from cars of this class as designed on other roads is an inward extension of the wing past the hinge post. As the leveling wing is usually designed, the inner end is hinged to the car, but in this case the wing is hinged at an intermediate point and the inner end extends to the rail, being jogged off at the ends of the ties. The brace arm which supports the wing against the side of the car when earth pressure is encountered consists of a steel crane attached to the car at one end and to the wing at the other end, by means of coupling pins. The coupling head at the side of the car permits of vertical adjustment.

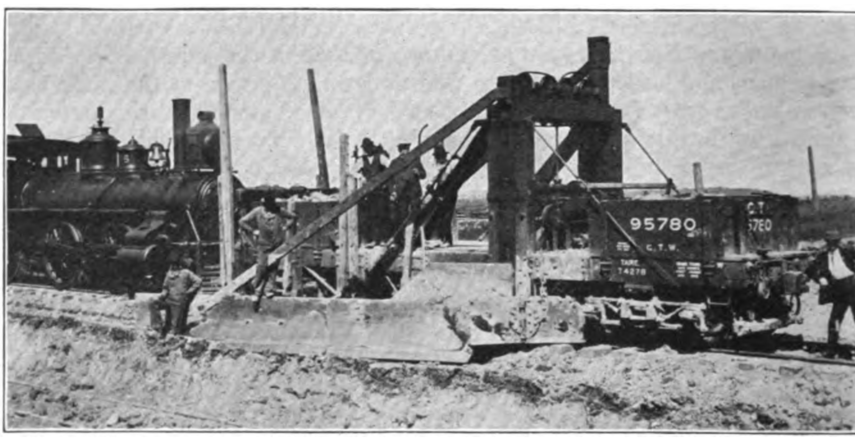


Fig. 286 A.—Jordan Spreader Car Adjustable by Compressed Air, G. T. W. Ry.

For spreading earth in double-tracking the Grand Trunk Western Ry. several cars were built on the Jordan style with wings adjusted by compressed air. As shown in Fig. 286A, these cars have a spreader wing on each side hinged to a vertical post sliding between two guide posts, as in the hand machines. The wing is held to its work by means of struts hinged to the side of the car and abutted against the wing. To adjust the wing for spreading to different widths there are sets of struts of different lengths When the wings are not in service the struts are folded up to a vertical position as shown in the picture. To hold the end of the wing down to its work there is a strut running from its outer end to the top of the hinge post, as shown. This strut consists of two plates, 6 ins. wide, with a piece of timber sandwiched between. To adjust the wing for depth of spreading, the hinge post is raised by means of a wire rope passed over pulleys at the top of a frame transverse to the car, and then attached to the piston rod of an air cylinder 16 ins. in diam. and 3 ft. 2¾ ins. long, standing vertically at the middle of the car. The wing is lifted by means of the air cylinder and cable and is lowered by its own weight. As in this work it is necessary to spread material on only one side of the track at a time, the air-lifting mechanism is fitted up to operate only one wing at a time. When it is desired to change operations to the other side of the track, the piston rod is detached from one cable and attached to the other. For clearing material from the ends of the ties there is a small auxiliary wing on each side, the hight of which is adjustable by means of a cable attached to the piston rod of an ordinary freight car brake cylinder anchored to the floor of the car in a horizontal position. The air for operating these wings is compressed on the car by means of an ordinary locomotive pump taking steam from the locomotive by hose connection. Air pressure is stored in a reservoir 24 ins. in diam. and 7 ft. long, placed crosswise the car.

In cutting down grades and straightening curved track on the Baltimore & Ohio Southwestern R. R. extensive use has been made of a spreader car built on plans covered by the Boutet patent, as many as seven of these cars having been in service at one time, spreading out material unloaded at the side of the track. This car (Fig. 287) measures 37 ft. over end sills and 9 ft. over side sills. The wings are hinged at three places on heavy underframing hung beneath the sills. These wings are each 21 ft. 2 ins. long and the spread of each extends to a point 13 ft. from the center of the track. The wing is formed of heavy planking faced with old boiler plate, and the planking is backed by heavy braced struts extending out at right angles to the side of the car. The side sills are cut away at a point 4 ft. 8 ins. back of each bolster, forming recesses into which the wings can be folded up in a vertical position when not in use, as shown in Fig. 288. When folded in this manner the wings stand against the intermediate sills, and the width over the folded parts becomes less than over the side sills, thus affording adequate protection to the wings in transit. The wings are folded by means of rope tackle attached to the top of a heavy post or mast stayed to the car

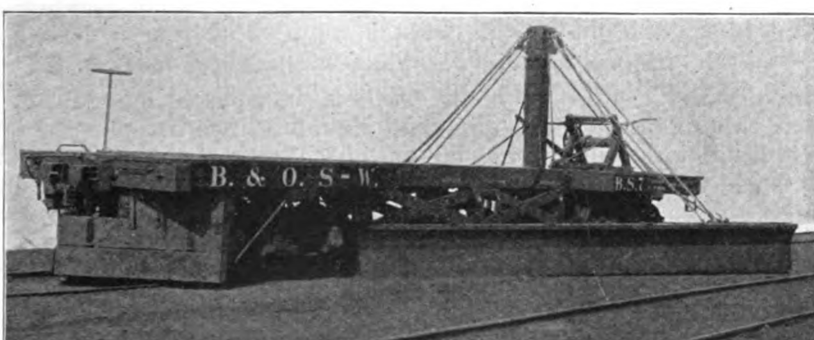


Fig. 287—Boutet Spreader Car, B. & O. S. W. R. R. (Ready for Service).

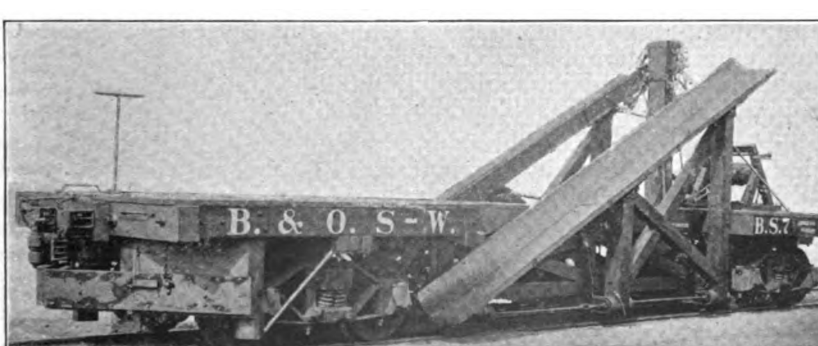


Fig. 288—Boutet Spreader Car, B. & O. S. W. R. R. (Wings Folded for Transit).

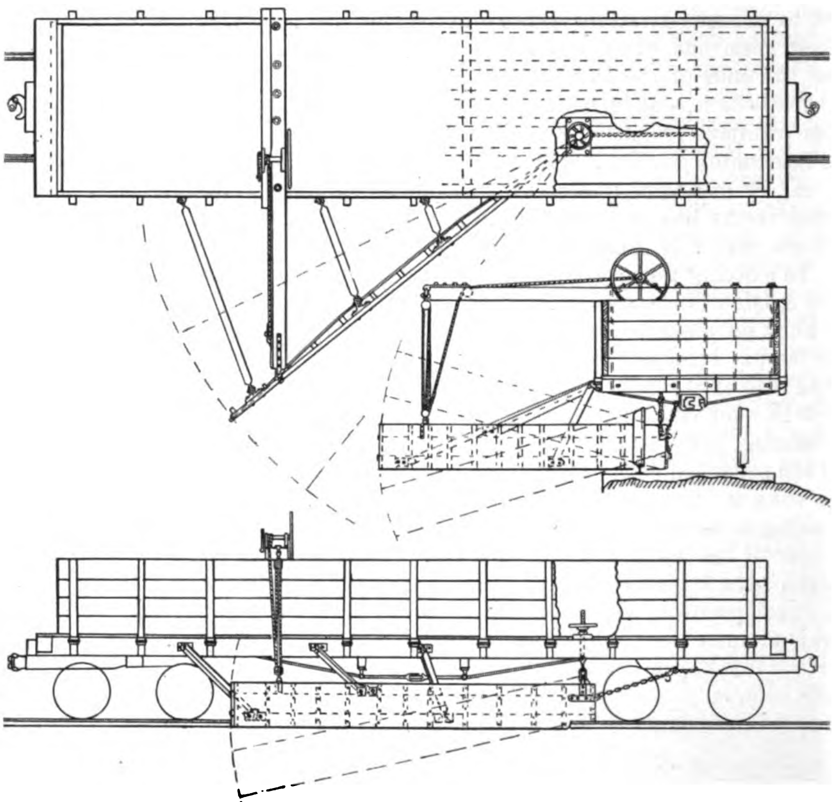


Fig. 289.—Donovan Spreader Car, Yazoo & Mississippi Valley R. R.

by brace rods. The hauling of the tackle is accomplished by means of a winch, back of the post, and to prevent the wings from dropping too low where the shoulder falls away at the side of the track, a stay chain of suitable length is run from the top of the mast to the outer end of each wing. The forward end of the car is provided with a pilot, which is used to spread any dirt that may chance to lie between the rails. The lower part of this pilot is made of a 12-in. plank, hung on hinges in such a manner that it reaches within 1 in. of the rail when the car is in use, but can be folded up out of the way while the car is being transported, as shown in Fig. 288.

An earth-leveling contrivance that has been successfully used on the Yazoo & Mississippi Valley R. R. takes the form of an attachment placed upon an ordinary coal car or gondola car at slight expense, without altering the construction of the car in any respect, the car being in special service only for the time being. The arrangement of the parts was designed by Mr. M. J. Donovan, of Vicksburg, Miss. There is a trussed wing swung from a point underneath the car and held in place by braces attached to the side sill (Fig. 289). This side wing or scraper is 28 ft. long and 24 ins. high. The depth to which the side scraper will level the material is regulated by block and tackle attached to the end of a 10x12-in. x18-ft. timber placed crosswise the car and held by long 1-in. bolts reaching through the sills of the car floor. On this beam there is a windlass for hauling on the tackle, so as to raise or lower the outer end of the scraper. The front end of the scraper is attached to a chain fastened over the car body bolster and it is adjusted in hight by a screw worked by a hand wheel, as shown. In operation the car is drawn over the track by a locomotive or coupled on behind the ballast cars and pulled along with them, thus spreading the material just unloaded. The reach of the scraper is 18 or 20 ft. from the cen-

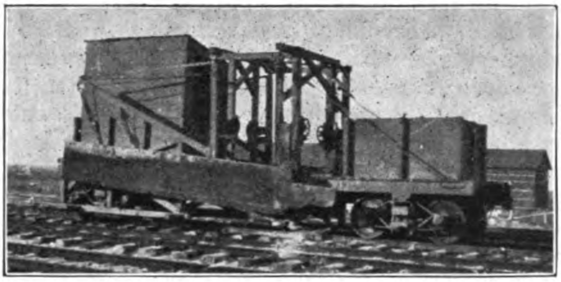


Fig. 290.—Ballast Spreader Car, Chicago Clearing Yard.

ter of the track, according to the hight at which it works. This car has leveled to a distance of 16 ft. from the center of the track, 20 car-loads of earth, extending along the track a distance of 800 ft., in 15 minutes. The wing is notched to fit over the rail, so as to flange the track and clear the material from the ends of the ties. For leveling down gravel unloaded between the tracks of the Chicago Clearing Yard for ballasting purposes, a car with winged scrapers arranged as in Fig. 290 was used. This machine consisted of a flat car loaded down with boxes of ballast at either end, with wings of heavy planking hinged to a beam adjustable vertically. The wings were supported at the back by struts, when in service, and at the middle of the car there was a timber framing, with a derrick at each side to adjust the leveling wing to its work.

In the foregoing descriptions of spreader and bank shouldering cars in service one recognizes two general types; namely, those with which the wings fold against the side of the car on vertical hinges, and those with which the wings fold upward on horizontal hinges. With the former type the wings may be adjusted for hight, but a little time is required to place the brace struts when putting the car into service and to take them down when folding the wings. With the latter type the wings are quickly handled, but they cannot be adjusted for hight.

As explained hitherto, spreader cars, as usually built, have been employed to level off material even with the sub-grade of the old track. The

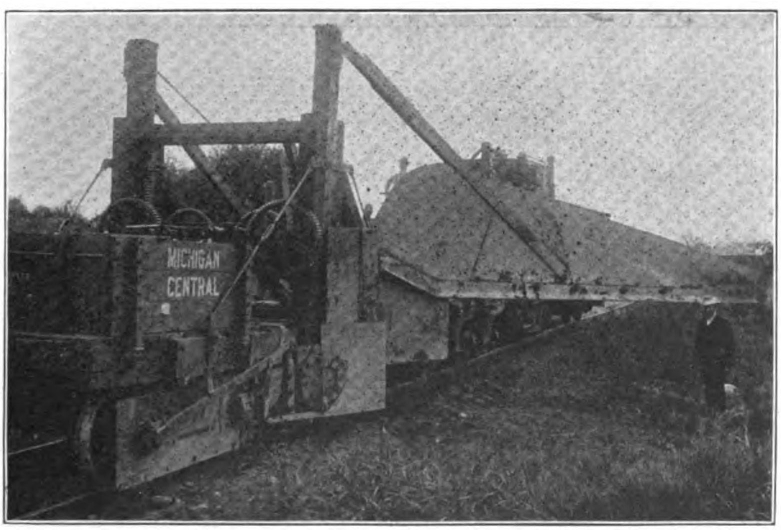


Fig. 290 A.—Torrey High-Bank Spreader Car, Mich. Cent. R. R.

Michigan Central R. R., however, has built and used cars which pile the material up into a bank at the side of the track and then strike it off at a level considerably higher than top of the rail. This type of car, known as a "high-bank spreader and leveler," was designed by the late A. Torrey, chief engineer. The purpose of the machine is to take material which is plowed off the cars to make roadbed for a second track, where the grade is to be raised, and heap it up into a bank, and then level it off on the elevated grade line. The machine was constructed by modifying the design of the wing on one side of a Jordan spreader car. The wing for the high-bank spreader is attached to the same lifting post at a higher point and arranged for such flexibility of adjustment that the earth can be spread on any level from a point 12 ins. below the bottom of the ties to a point 4 ft. 9 ins. above top of rail. The construction of the high wing is illustrated in Fig. 290A, where it is shown in position for spreading earth horizontally at a level about 3 ft. above top of rail. The wing is formed of plank, faced on both sides with

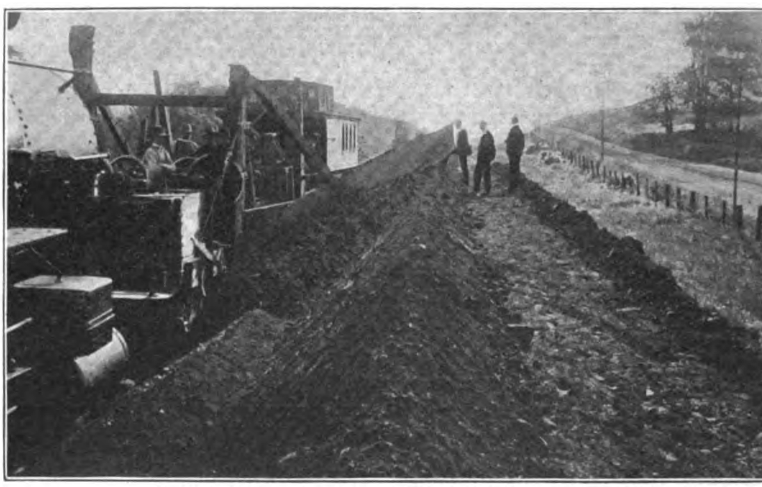


Fig. 290 B.—Torrey High-Bank Spreader Car Elevating Material.

Fig. 290 C.—Torrey High-Bank Spreader Car Levelling Material.

boiler plate, and is attached at the inner end to a heavy plate hinged to the lifting post. To facilitate the adjustment of this high-bank wing to varying inclinations the wing is pivoted to the end of a diagonal brace arm, which may be attached by means of a pin at any of the numerous holes which appear in the illustration. When it is desired to tilt the end of the wing upward for plowing dirt to a level higher than the track, the inner end is depressed and made fast to the hinged plate by a pin connection.

A view of the machine in operation, plowing dirt up to a level about 4½ ft. higher than the track, is shown in Fig. 290B. The material was first plowed from flat cars by a Lidgerwood unloader and train plow, and then the high-bank leveler was pulled along with the wing set to plow the material to the top of the bank already in process of formation, as shown. The next step consists in setting the wing horizontally to spread the elevated material across the bank. This operation is shown in Fig. 290C. Figure 290D is a side view of the same embankment. The men seen standing in the picture give the reader an idea of relative elevations.

Fig. 290 D.—Completed Work Done with Torrey High-Bank Spreader Car.

The advantages derived in the use of this machine are quite important. Referring to Fig. 290D, it will be seen that the new second track can, if desired, be laid 6 or 7 ft. higher than the sub-grade of the old track. Otherwise, to get the new track up to this level it would be necessary to first construct it and then raise it by stages and place the material underneath with shovels. Where this machine is used the new bank is first graded to the higher level, the new track is laid thereon and surfaced and put in shape for the traffic. The old track is then lifted and blocked up on old ties and the material is dumped and plowed over with a spreader car to fill the space underneath. The machines have worked successfully in both sand and heavy clay material, and there has been no trouble in keeping them on the track. When the machine is in service it is operated to plow up each train-load of material immediately after it is unloaded.

In filling for second track against an old slope it is a good plan to bench or step the slope by plowing furrows, to prevent the new fill from sliding. Time should be allowed fills made for second track to settle well before laying the track, because where such is not done it is difficult to keep the track in good surface for some time after the regular trains begin to use it.

Tracks lying close together should be at the same level, and they should also be everywhere a standard distance apart. The most convenient, and certainly the clearest, basis for measurement between the two tracks is between centers, and such affords the most logical data for engineering calculations. The employment of a certain distance between rails to express the distance between the two tracks is rather indefinite and unsatisfactory, for the width of head in rails of different sections varies. A standard distance between centers does not, however, preclude the use of a gage between rails in lining the new track with reference to the old. Where the two tracks are parallel, and on the same roadbed, side by side, and the old track is in good surface and alignment, there is no need for setting either center or rail grade stakes for the new track. Twelve feet between track centers gives sufficient clearance between trains, and on some roads, including, among others, the Boston & Maine, the New York Central & Hudson River, and the Baltimore & Ohio, this is the standard distance; 13 ft. is, however, a more common standard distance; and on a few roads (mostly in the prairie states) 14, and even 15, ft. is standard. Fourteen feet gives room for a ditch between the tracks, and some roads ballasted with dirt are provided with such a ditch. The distance between centers of double track is generally and preferably made a convenient measurement, like an even foot or half foot. It adds to the appearance of things

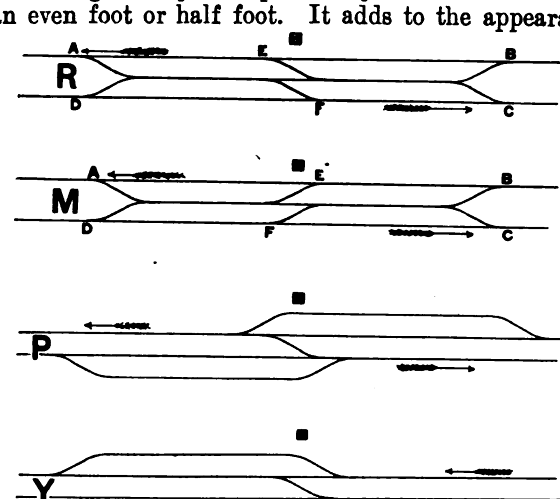


Fig. 291.—Double-Track Passing Sidings.

to fill in full between tracks with ballast, and where gravel is used for ballast this can be done. It also makes good footing for flagmen to alight upon when dropping from moving trains, and affords a supply of ballast for use, as it may be needed, when track is raised and surfaced.

113. Danger to Workmen.—There is one aspect of double-track operation which is not so pleasant to contemplate, knowing, as all do, the freedom with which pedestrians habitually use the track almost everywhere in this country. It is very seldom that any one is struck by a train while walking along a single-track road, because when a train approaches one will get off the track and stay off until after the train has passed. On double track, however, nine people out of ten, if walking along one of the tracks, will, at the approach and passing of a train, step over and walk along the other track. The result of such negligence is a frightful loss of life. During the interval between some little time before an approaching train arrives and for some little time after it has passed, the noise from it will generally drown the sound of any other train which may be approaching, or even whistling; so people who are occupying one track while a train is passing on the other, if not watching, are in much danger of being struck by another train if it should come at this time, especially where the latter is on the outer track of a curve. Many track hands have been killed in this way. It should be a rule strictly enforced that, *under no circumstances will any employee be allowed to work, walk or remain on one of the main* *tracks while a train is passing on an adjacent track.* Disregard of this rule, so obviously essential to safety, was the responsible cause of the wrecking of a passenger train with a track jack, on the Old Colony R. R., at Quincy, Mass., on Aug. 19, 1890. In this wreck 23 people were killed, and since, in the popular misunderstanding, the fault has always been charged to the failure of the track jack to trip, it is well enough that the facts should be stated. The jack was being used on a curve while a train was passing on an adjacent track. In this situation the passenger train, running fast, got so close to the men before they knew of its approach that they were compelled to jump for their lives. The man in charge of the jack (who, by the way, had worked on the track only a few days), was so frightened that he jumped without even attempting to remove the jack. The locomotive was derailed to the outside of the curve and the cars crashed into it. The wreck was therefore due to no ordinary combination of circumstances.

On double track the trackmen should also be on guard against the movement of trains in the reverse direction, which is sometimes necessary when one of the tracks is blocked by a wreck or other obstruction. The fact that such movements are usually of seldom occurrence is one of the elements of danger. On double track the danger at grade highway crossings also is imminent, for so many people will attempt to cross, or drive a team across, just as soon as a train has passed, without taking due care to look for another train moving on the other track. Wherever the public is in the habit of walking on the track a good way to stop it is to scatter good-sized lumps of broken furnace slag over the track and on the shoulders and between the tracks, for some distance in each direction from highway crossings. Such material at least spoils the roadbed for a bicycle path.

114. Sidings for Double Track.—Sidings for double track can best accommodate both tracks if arranged between the two, as then a single siding may serve the traffic in both directions. When changing from single to double track where lap sidings have been in use, such sidings can be made the main tracks of the double line and the old main line between them be used for a siding or passing track. Figure 291 shows two ways (*R* and *M*) of arranging a middle passing track for simultaneously side-tracking trains headed in opposite directions. In arrangement *R* the trains pull in at *B* and *D* and out at *E* and *F*, at the same time, without interference; and while standing, the locomotives of the two trains are together and at the telegraph office or signal tower—a desirable method of handling trains; and the switches opposite the tower are trailing switches. By arrangement *M* trains pull in at *E* and *F* and out at *A* and *C* at the same time, without interference, and, while standing, the cabooses are together and at the tower or telegraph office. By arrangement *R* the switches at *E* and *F*, being under the observation of the telegraph operator or leverman, give him opportunity to know that the switches have been closed after the trains have left the siding; whereas by arrangement *M* he would not necessarily know this unless the distant switches at *A* and *C* were operated from his tower or under control from that point. In *M*, the switches opposite the tower are facing switches. In case more than one train moving in each direction is to be accommodated the siding is simply made of length to correspond. The great convenience in locating the siding between the tracks is that in case of a rush of freight business the whole siding capacity for both tracks may be used by trains running in either direction without having to use or move across the other main track; but in order to effect this arrangement in *M* the facing switches *B* and *D* are required, which is an objectionable feature, and for which reason they are sometimes omitted. Arrangement *R* is therefore the preferable one, because the capacity of the whole siding is available to trains from either direction without introducing an extra facing switch.

In order to have a middle siding on straight line one or both main tracks must be curved reversely at each end of the siding, for which and for other reasons passing tracks are often located outside the main tracks, as shown by arrangements *Y* and *P*. The difference in the arrangement of the two determines simply whether trains shall pull in at the tower or pull out at the tower, the relative advantages being the same as were just explained for middle sidings. The arrangement with a middle siding occupies less room in width of right of way than that of outside sidings, but it does not permit of connection with branch side-tracks independent of main line, as do outside sidings. Outside sidings also afford a basis for the construction of third and fourth tracks, in case the development of the road proceeds that far. It is to be noted that when the switches opposite the tower are operated from the tower, arrangements *R* and *P* permit trains to pull out of the siding without stopping to close the switch, and arrangements *M* and *Y* permit trains to pull into the siding without first stopping to open the switch, either arrangement operating to facilitate train movements.

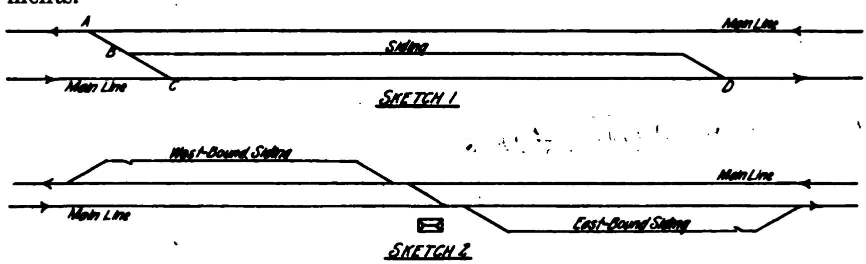


Fig. 292.—Double-Track Passing Sidings.

The safest but least expeditious arrangement of double-track passing sidings is to lay spur tracks leading from trailing switches, by which arrangement, of course, the trains must back into the siding, as when using a crossover, which is habitually laid trailing to the train movements. An arrangement for laying a double middle siding with all switches trailing is shown as Sketch 1, Fig. 292, *AC* being a crossover and *BD* the passing siding, which may be long enough to hold trains backed in from both main tracks.

In both of the sketches *P* and *Y*, Fig. 291, the crossover is located within the lap of the outside sidings. If it is intended to have the trains pull in at the tower, as in Sketch *Y*, it is convenient to arrange the switches entering the sidings to face each other and stand far enough apart to lay the crossover in between, as in Sketch 2, Fig. 292. In emergency this arrangement permits backing a train over from either track into the siding for the other track, by a direct movement, and when pulling back again the train moves straight ahead through the crossover. Such is the arrangement of passing sidings on the Philadelphia division of the Baltimore & Ohio R. R. The sidings are 6000 ft. long, extending each way from a crossover which stands opposite an interlocking cabin, from which the crossover and the switches entering the sidings are operated. The switches at the outgoing ends of the sidings are controlled from the cabin by electric locks. In connection with this lock there is a visual signal which gives the indication of the right of a train to leave the siding for the main track. For protection against fouling main line at the ends of these sidings there are the usual derailing switches, and as the main line is protected by automatic semaphore block signals, the switches are electrically connected with the block system to show "danger" at the first block signal in the rear whenever a switch is opened.

CHAPTER IX.

TRACK TOOLS.

115.—Reports of the Interstate Commerce Commission show that, on the average, about 62 per cent of the cost of track maintenance is represented in the pay rolls of the section men and foremen. The cost for labor in track maintenance is therefore a high figure. Now nearly all of the time of trackmen is necessarily employed in work which involves the use of tools; and hence the selection of proper tools, and a knowledge of how they should be used are matters of great importance in the expense of keeping track in repair. By looking attentively to these things the roadmaster or supervisor may sometimes find opportunity to reduce the expenses of his department without curtailing its effectiveness. By such supervision it is often possible to increase the output of labor in such a way that the laborer is unconscious of it. A poor tool will discourage even a good man, while a good tool gives a lazy man no excuse, mental or otherwise, why he should not do fair work. As track labor is usually paid about the lowest rates paid for any labor, it is not to be expected that all men will take an enthusiastic interest in the work. Many men, after they get somewhat acquainted with the work, acquire a sort of indifference to it and naturally fall into such an attitude, between the work on the one hand and the vigilance of the foreman on the other, as affords them, on the whole, the greatest ease of mind and body. Such being the case, it is highly important that any policy or measure which can increase the efficiency of the work in spite of any little faults common to human nature, shall be taken advantage of. Now there is nothing which will so induce a man to turn out good work, in both quantity and quality, as will a good tool. Out of curiosity he will wish to "see the thing work" and before this curiosity has entirely worn away he will have established a gait which he cannot consistently slacken.

It should be a rule with roadmasters to provide only the best tools; keep them in good working condition; teach men how to use them; and if they are ordinary men there is but little else concerning the work which will need special attention. The first cost of good track tools, as a rule, is but little, if any, more than that of poor ones, and the ultimate cost is far less. The points which should be looked after in selecting tools are two: first of all, tools should be of such form and weight as will best adapt them to the work and enable them to be handled with such facility that there can be turned out a maximum of work for the time they are in use; and secondly, tools should be durable. A set of tools which would work well on one section might need some modification in apparently minor but important particulars to adapt them to the work of another section where the conditions are different. Tools should be as light as is consistent with the strength of the material. Reduction in the weight decreases the load to be carried around by the men and, as many tools are paid for by the pound, such reduction effects a direct saving of expense to the company. On the selection of tools one might enlarge to a great extent. Of all track questions that laymen are sometimes called upon to settle, they never get farther at sea in any than when selecting track tools.

116. Tools Required.—Each section crew should be supplied with enough tools to keep each man busy while engaged at the different kinds of ordinary track work, and there should be some to spare of such kinds as usually have to be sent away at times for repairs. There may arise special occasions when all the men in a crew will need certain tools of the same kind, but if such occasions are only of seldom occurrence it is not worth while to provide for them. Take, for instance, the matter of wrenches. It is seldom that more than three wrenches will be in use at the same time in a crew of six men, for the reason that in most kinds of section work requiring the use of the wrench there will be other parts of the work requiring the use of hammers, claw bars, etc. The same applies also to the gage. A second gage may lie in the tool house for years unused; and besides, a gage is very easily duplicated, if emergency require. A narrow strip of board notched at the ends to fit over the rail heads answers very well for temporary use.

The item of tools for a whole division is such a large one that it is not advisable to place on each section all the tools that may possibly be needed there on some special occasion. Just enough to answer such needs as have been found in general experience should be furnished and no more. An over-abundance of tools has a tendency to make foremen careless of them and less watchful that all taken out of the tool house in the morning get back in the evening. Tools lost will be most diligently looked for when such deficiency creates a shortage in the number necessary to supply immediate needs. At headquarters, however, there should be kept a sufficient supply to be drawn upon as tools of the different sections become broken beyond repair, worn out or lost, and such will generally answer any unusual demand which may come suddenly in case of washouts, wrecks, slides, etc. Below is given a list of tools supposed to be a sufficient supply for a section crew consisting of a foreman and 6 men:

Adzes	2
Ax (chopping)	1
Hand Ax	1
Auger, 2-in.	1
Claw Bars	2
Crow Bars	0
Pinch Bars	6
Raising Bar	1
Tamping Bars	8
Brace and Bits	1
Brooms (coarse)	2
Brush Hooks	2
Hand Car	1
Push Car	1
Car Chains	2
Track Chisels	12
Cold Chisels	2
Wood Chisel	1
Curving Hooks	2
Chalk Line	100 ft.
Ditch Line	150 ft.
Drawshave	1
Cups or Dippers (tin)	2
Files	3
Flags, red	4
Flags, green	2
Ballast Forks*	4
Gage	1
Grindstone	1
Spike Hammers	4
Sledge Hammer (16 lbs)	1
Striking Ham'r (10 lbs)	1
Nail Hammer (claw)	1
Ballast Hammers*	6
Hatchet	1
Hoe (garden)	1
Jack (track)	1
Switch Key	1
White Lanterns	2
Red Lanterns	2
Green Lanterns	2
Level Board	1
Spirit Level (pocket)	1
Switch Locks (extra)	2
Mattocks	2
Oil Can, 1 gal.	1
Oil Can, 2 gals.	1
Squirt Oiler	1
Padlocks	2
Picks	8
Tamping Picks*	8
Hand Punch	1
Rake (garden)	1
Rail Drill	1
Drill Bits	6
Rule, 2 ft.	1
Grass Scythes	4
Brush Scythes	4
Snaths	4
Track Shovels	8
Scoop Shovels	4
Long-handle Shovel	1
Hack Saw Frame	1
Hack Saw Blades	12
Hand Saw	1
Crosscut Saw	1
Screw Driver	1
Spade	1
Steel Square	1
Tape Line (50 ft. graduated to tenths)	1
Rail Tongs	4
Tool Box	1
Tool Checks	6
Torpedoes (with box)	24
Verona Spike Puller	1
Vise	1
Water Pail or Jug	1
Weed Scuffles	6
Wheelbarrows	3
Whetstones	4
Wire Stretcher	1
Track Wrenches	3
Monkey Wrench (8-in.)	1

*Needed only in stone ballast.

A few extra handles for spike hammers, picks, axes and adzes, and an extra white and extra red globe for the lanterns should be kept on hand at all times. It is well to oil wooden handles for track tools, including shovel handles, before they are used, as it will prevent season checking and render them less absorptive of water when exposed to rain. In a wooded country 3 peavies (*K*, Fig. 309) or 3 cant hooks (*G*, Fig. 309), and 5 or 6 iron wedges for wood should be furnished each section. Where heavy rocks are liable to slide or roll upon the track, drills or jumpers, powder, fuse and wedges for stone should be kept on the section. Two or three jim-crows should also be kept at headquarters, and each foreman advised to send for one, if needed, and to return it when he is through with it. Sections which include large yards or numerous switches should be supplied with a rail bender or jim-crow each; or on roads where the switches are numerous and more or less evenly distributed, a jim-crow might be furnished alternate sections, so as to be conveniently accessible to each crew when wanted. If a day track-walker is employed he should be furnished with a spike hammer and wrench, each of lighter weight than ordinary. Night track-walkers should furnish their own lanterns. On sections where tie plates are used a tie plate gage, sets or followers and beetles should be furnished. In mellow soil at least one post-hole digger should be supplied each section. On sections where culverts or bridge openings are liable to be obstructed by floods a half dozen pike poles and 150 ft. of 1-in. rope, with single and double blocks, are useful appliances at times. A description of the most commonly used tools, with remarks upon their use, now follows.

117. Shovels.—First in importance among track tools—traditionally so, at any rate—is the shovel. The one best adapted to track work has a short handle and a square-pointed blade: in the parlance of trackmen it is known as the "Regulation No. 2." Its appearance is so generally familiar that it need not be illustrated here, but a reference to certain features of construction and the dimensions may prove of value. The proper size of blade is about 12 ins. long, and 9½ or 10 ins. wide at the working edge or "point." The handle should be about 27 ins. long (direct measurement), from the top of the blade, and so crooked that when the blade is in position for filling, on a level surface, the end of the handle is 18 ins. above the ground. This is the hight of the knee of a man of ordinary size when the leg is bent as in the act of shoving the blade forward to fill it. When a handle is crooked or hung to the blade in this manner the straight part of the handle makes an angle of about 33 deg. with the straight or flat part of the blade, which refers to the bottom of the blade for a length of about 6 ins. from the point. Owing to this angularity of the handle the over-all length of a shovel with parts of the above dimensions is about 38 ins. The diameter of the handle is about 1½ ins. at the straps, tapering to 1¼ ins. at the tip. The weight of such a shovel, with an ash handle and a blade $^3/_{32}$ in. thick, is 5¾ lbs. The weight should not exceed 6½ lbs. As the shovel is much used for tamping, the blade should be stiff. The best shovels are now made from a single piece of crucible cast steel, the blade, socket and straps all forming one piece, without weld or rivets. The thickness of the blade for light work is $^1/_{16}$ in., but for railroad service it should be at least $^3/_{32}$ in. or about No. 11 Brown & Sharp gage. The blade can also be made to increase slightly in thickness from point to socket, so as to give added strength or stiffness where the strain is most severe. A committee of the Roadmasters' Association of America, in 1894, recommended a shovel made from one piece of crucible cast steel, with "straps strengthened by a socket for the handle extending at least 1¾ ins. above the blade."

Where dirt ballast is not used an all-wood handle is preferable to a wood handle with a malleable tip. For adapting shovel handles to the work of tamping dirt ballast several forms of cast or malleable iron "D" tips are on the market. One form (Jackson's patent) is shown in Fig. 293. The grip is hollow and is formed in suitable shape for tamping, but is rounded at the corners so as to be easy on the hand. These metal tamping tips are also useful in repairing broken shovel handles. If shovels are properly cared for they will not be left out in the rain or exposed to a hot sun. In the former case the handle will swell and sliver itself, turn out the edges of the straps or burst the rivets and loosen the straps. In hot sun the grip is liable to check, get loose and revolve on the end rivet to the annoyance of the shoveler.

Although the work of shoveling with a short handle is somewhat severe on the back, at first, men can, after they get accustomed to it, handle a given quantity of material with a short-handle shovel more easily than with one having a long handle. The blade of a long-handle shovel is not as large as that of a short-handle shovel, for the reason that a man cannot lift as much material with a long handle as he can by taking hold up close to the load, as he necessarily does when using a short-handle shovel. A long handle has to be griped more firmly in the hands, although it is not so easy to gripe and hold as is the short handle; it is therefore more tiresome to the hands and arms than is a short handle. It takes up room and does not permit as many men to work in a given space as the short handle does. Even laying aside track work, the long handle is inferior to the short handle anywhere one takes it except in digging post holes and deep, narrow ditches. Notwithstanding such considerations, however, some roads use it in all kinds of track work.

Fig. 293.

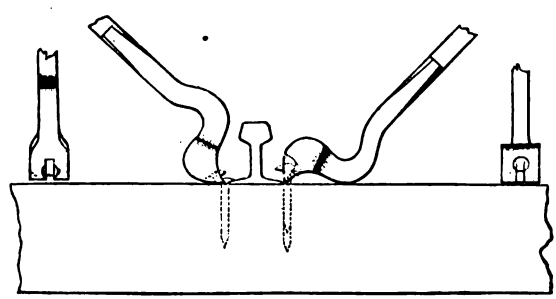


Fig. 294.—The Hamm Claw Bar.

One would naturally suppose that any man could learn to shovel dirt without instruction; but such is not the case. Some men tire themselves out at it and still do but very little. In casting material with a shovel there are two things to observe in order to make the work easy: the shoveler should continually make or seek a horizontal bed upon which his shovel may be easily pushed under the material, the end of the handle then coming at such a hight that the back of the hand grasping it may rest against the inside of the leg at the knee; and when casting an ordinary distance one heel should be kept in place. If one is casting toward the right he should keep the left heel in place, and simply turn toward the right by moving the right foot when in the act of making the cast; when casting toward the left he should keep the right heel in place, moving only the left foot. It is tiresome to keep up a fair gait with a shovel and at the same time to be needlessly stepping around. Some men while shoveling will, in addition thereto, in the course of a day, take enough unnecessary steps to walk several miles.

A shovel blade worn off to less than 9 ins. length is practically worn out for the purpose of handling material or tamping, and its further use becomes unprofitable. Every day's work with such a shovel will, compared with the use of a new tool, lose to the company at least one third of the price of a new shovel. After laying aside enough old shovels at the tool house to use for cutting grass in the track the rest should be turned in to headquarters, as the handles might be of further service. If the edge of a shovel blade turns up one should not flatten it out again with a hammer, but hold the blade on the rail and take a square cutting across it with a track chisel, cutting off also the sharp corners where the blade turns up at the side. Each man should be allowed to have his own shovel, if he so desires, as he will then be more interested to take care of it. The cost of shovels in track repairs is a large item.

The long-handle shovel included in the list of tools is for digging holes and narrow ditches, and should be round pointed. Scoop shovels are useful for handling snow and cinders. They will handle snow which is quite solidly compacted and, under such conditions, the scoop is a much better tool for the purpose than the snow shovel. Snow shovels with wooden blades are of but little account around the track. A snow shovel with wooden handle and sheet steel blade about 13 or 14 ins. wide and 13½ to 15½ ins. long is a good tool for clearing snow from depot platforms and from side-tracks and other places where the snow has not been compacted, but for all purposes the scoop shovel is better. Mention has heretofore been made of the ballast fork, for handling stone ballast. This tool is similar to a dungfork, but somewhat larger and stronger, and with closer tines. It has a track-shovel handle (Engraving *D*, Fig. 309). The standard fork adopted by the New England Roadmasters' Association has 10 tines 13¼ ins. long, spaced 1 in. apart, the width of the fork being 10⅞ ins. The Pennsylvania R. R. has two standard ballast forks, one being 12¾ ins. wide, with 14 tines ¼ in. wide and 13¼ ins. long, and another, for coarser material, 12 ins. wide, with eight tines $^5/_{16}$ in. wide and 13¼ ins. long.

118. Picks.—In railroading, the proverbial mate for the shovel is the pick. The kind used on railroads (*A*, Fig. 295) is commonly known as the "clay pick." One end should be wedge-shaped, having an edge about ⅞ in. wide, and the other end should be pyramidal; the two ends are generally known as "wedge-pointed" and "pick-pointed," respectively. The wedge point is useful for pulling ballast from the sides of ties in preparation for tamping with the bars, and also for picking material which is not very hard or compact. The pick point is made for picking hard material, or to enable the pick to hold fast when struck into timber or ties, without breaking off the point—as would happen to the wedge point. Picks having solid cast steel eyes are best, as they do not split. If properly made of wrought iron, however, they answer quite well. A pick made of iron is usually formed by welding together, over a properly shaped mandrel to form the eye, two pieces of iron, ½x2x12 ins., and drawing out. The ends or points are made by splitting the iron and welding pieces of cast steel into them. The eye should be oval, 2x3 ins., and 2½ or 3 ins. deep. The length of a new pick from point to point should be about 22 ins., and when worked down to about 18 ins. it should be pieced or drawn out again. A pick longer than 22 ins. is rather unwieldy, and one less than 18 ins. in length is too short. A weight of 6½ or 6¾ lbs. exclusive of the handle is heavy enough for a pick.

A pick, to work well, should be anchored to a radius of about 32 ins., and should have a handle 3 ft. long—which is the usual length. The anchoring of the pick is an important feature, for if the pick is straight or nearly so it will jar the user's hands in working it, and if it is curved too much the picker cannot strike a straight blow. When the pick is properly anchored, the secret of loosening material with it, if the material is not too hard and compacted, is to strike and draw a little at the same time. Unless the material is very hard there is no necessity for swinging the pick over the shoulder in striking: simply raise it up in front of the body and draw toward yourself as the point enters the ground. When using a pick for a lever, as when striking it into a tie to spring a rail, one should pull on the free end of the pick, so that it will not be necessary to bear too hard on the handle. In opening out a tie to be bar-tamped, after the tie has been raised, the proper way is to strike into the ballast a few blows, first toward the rail, each side of the tie, to loosen the material, and then turn and draw it out with the wedge-pointed end of the pick. Picks to do good work must be kept sharply pointed. When it is inconvenient to send them to the shop they may be easily and quickly sharpened for a few times by heating in a fire beside the track and drawing out the point with a spike hammer, using the rail for an anvil. An ingenious foreman or section hand ought, after practicing once or twice, to be able to give the metal the right temper.

A tamping pick differs from an ordinary pick only in having in place of the wedge point a tamping head or rectangular piece of steel welded on. A head $2\frac{1}{4}$ ins. long by 4 ins. wide by about $\frac{5}{8}$ or $\frac{3}{4}$ in. thick at the edge is a common size for this tamping end, and this form is called the "T" tamping pick, shown by Engraving *B*, Fig. 295. The standard tamping pick adopted by the Roadmasters' Association of America is of this form. It is $24\frac{1}{2}$ ins. long from tip to tip, the center of the eye being $12\frac{1}{2}$ ins. from the pick end and 12 ins. from the tamping end. The tamping head is $2\frac{1}{4}$ ins. long, 4 ins wide, and $\frac{1}{2}$ in. thick on the striking edge. The weight of the tool without the handle is $8\frac{1}{2}$ lbs. Another form, known as the "V" tamping pick (*C*, Fig. 295), differs from it slightly in having the tamping end of

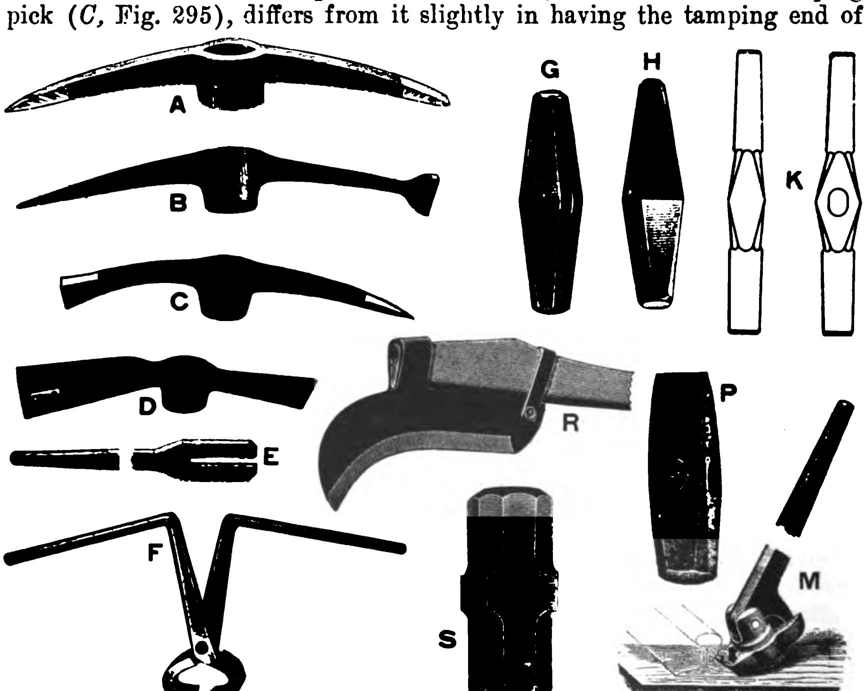


Fig. 295.—Various Track Tools.

the pick about 2½ to 3 ins. wide and the same thickness, but drawn out gradually back toward the eye, instead of having a rectangular piece welded to the end of the pick proper. It gives more metal to draw from when the pick needs repairing, but is heavier, weighing about 9 lbs.

Eyeless picks are extensively used. This pick is constructed of one solid bar of hard steel, to the middle of which two malleable iron lugs are riveted to form the socket. The handle is held in the socket by a bolt passing through one of the lugs and the handle, and screwing into the other lug, as shown in Fig. 301. These lugs protect the handle from being cut when striking under the rail with the pick, and if the handle shrinks and gets loose it may be tightened by screwing up on the bolt. The mattock (*D*, Fig. 295) is useful in cutting roots and sod, in ditching, and in other rough work at grubbing, for which an ax is not suitable. It has two long steel blades, one like an ax, the other like an adz. The two edges thus cut in planes at right angles to each other, the "cutter" being 4½ to 6 ins. long, with a 3 or 3½-in. edge, and the "hoe" end 8 to 8½ ins. long, with a 3½ to 4¼-in edge. The tool is 16 to 17½ ins. long over all and weighs 5 to 6 lbs. without the handle. The eye should be made to fit the common pick handle. The grub hoe, which is a mattock minus the cutter, is not as useful as the mattock for railroad work.

119. Hammers.—The spike hammer or maul should be made of solid steel. The blow from a hammer made wholly of steel is more effective than that from an iron hammer of equal weight faced with steel, swung with equal force: the softer material in the body of the hammer has the effect of cushioning the blow; that is, it undergoes more compression from the reaction of the blow than is the case with a hammer made of solid steel. This effect is most noticeable when spiking hardwood ties or striking chisels. The best weight for general section work is 8 lbs., without the handle. The proper length for section work is about 10¾ ins., and the hammer should be double faced, the two ends or faces being circular and about $1^7/_{16}$ ins. and ¾ in. diameter, respectively. These faces should be almost flat—that is, but very slightly convex—and their edges or circumferences should be rounded off but very little. At the eye the cross section should be rectangular, with slightly beveled corners, and between this and the faces the metal should be nicely drawn out so as to meet the faces without beveling. The shape of the eye is oval, and the usual size ¾x1¼ ins. The center point of the eye should be about 5 ins. from the larger face, so as to leave the other end a little longer for reaching spikes behind guard rails. Of the hammers shown in Fig. 295, Engraving *H* illustrates these requirements better than Engraving *G*. For track-laying, where heavy blows count, a hammer 1 or 2 lbs. heavier, or one weighing 9 or 10 lbs. (according to the quality of the timber—soft or hard), is better; and there is some advantage to be had if it is about 2 ins. longer—say 12½ or 13 ins. long—because then the spiker does not have to stoop so low in delivering the blow. For general section work, however, there is a great deal of spiking which does not require heavy blows continuously, and the spiker does not swing the hammer over his shoulder so frequently as in continuous driving in new timber. For such purposes the 9-lb. hammer is too heavy and a hammer 12½ ins. long is somewhat unwieldy for quick work. Men who do a good deal of work around switches will understand what I mean. In a general way it may be said that the contractor, whose work is mainly to lay track, needs a heavier and longer hammer than the one most serviceable for the purposes of general section work.

Spiking hammers are usually made from 2x2-in. bars of cast steel. The eye is formed by first punching the blank with a taper punch, allowing the stock to swell out, and then a round mandrel is inserted in the hole and the blank squared up, leaving an oval hole. The ends are drawn out on taper dies, under the hammer. Track chisels are made in much the same way. In order to hang the handle properly it is important that the eye should be straight through, or perpendicular to, the hammer head. If the hole is not just true it may be corrected by putting the hammer in a vise and filing the hole straight with a round file. Another hammer of quite different shape from the foregoing is used to some extent. The center portion for a length of about 5 ins., containing the eye, is of square section with beveled corners, tapering to ends of circular section, as shown by Engraving *K*, Fig. 295. The faces at the large and small ends are about $1\frac{1}{2}$ and $1\frac{1}{8}$ ins. diam., respectively, the usual length is 15 ins., with the center of the eye 8 ins. from the larger face, and the weight about 10 lbs. These hammers, commonly known as the "Pittsburg" pattern, do fairly well in track-laying, but are ill proportioned for general section work, being too long.

Experienced trackmen differ somewhat in their views regarding the proper shape and proportioning of hammers, and as much as 2 or 3 lbs. in weight. Those whose ties are principally or wholly of hard wood will naturally enough select the heavier hammers. The standard handle is 3 ft. long. If the edges of the face get battered off, the face should be repaired by heating and dressing down. A face too convex, but otherwise in good condition, may be flattened down by holding it in a fixed position against a grindstone. Like chopping with an ax, the knack of driving spikes requires some practice before good work can be done. To do it easily a man must acquire an easy swing, using the full length of the handle, and be able to strike accurately without walking around too much. Muscle-bound men never make good spikers, because they always measure themselves before striking; they first try to get the feet into some certain fixed position, and thus time is lost.

Ballast or "napping" hammers are for breaking stone. They should be solid steel, about $5\frac{1}{2}$ ins. long, and weigh 3 to $3\frac{1}{2}$ lbs. Each of the two faces should be about 1 or $1\frac{1}{4}$ ins. in diameter, or octagonal, and the faces should be quite convex, rather than flat like the face of a spike hammer. The handle of a napping hammer is made small, or considerably reduced in section near the head, so as to give it spring and save it from splitting from the shock of the blows, and to prevent stinging the striker's hands. For breaking up large stones a 12-lb. stone sledge with one convex face and a pein end (*P*, Fig. 295), somewhat similar to a mason's hammer, is used.

A railroad sledge hammer should be double-faced (Engraving *S*, Fig. 295) and weigh about 16 lbs. For striking chisels a 10 or 11-lb. sledge makes the best striking hammer. The faces being large, enables one to strike a fair blow which does not hack or batter the head of the chisel as badly as does the ordinary spike maul, which, except in emergency, should not be used for a striking hammer. Sledges and napping hammers, like spike hammers, should be made of solid steel. An ordinary carpenter's nail hammer or claw hammer is a tool always much needed in section work, but, strangely enough, is seldom furnished. A track-walker's hammer should weigh about 4 lbs. It should have a spiking face on one end and a narrow adz edge on the other end for digging the dirt from the flangeway in crossings and for "bleeding" the ends of ties that are "churning" water.

120. Wrenches.—Track wrenches are sometimes made of 1-in. round iron, with head and jaws of steel, about $\frac{7}{8}$ in. thick, welded on. It is considered better practice, however, to die-forge the tool out of solid steel, and it is to some extent the practice to punch the material out of old steel boiler plate. Short pieces cut from the ends of soft steel bars in the car shops are also worked up into wrenches and tamping bars to some extent. High carbon steel is not considered good material for track wrenches, as the tendency with this material is to break in the jaws. In order to catch a nut readily the jaws should be no longer than is necessary to engage the corners of the nut. Where hexagonal nuts are used the space between the jaws should conform to the shape of the nut; or at any rate the space should be so curved into the shank that an apex or corner of the nut cannot reach the shank and interfere with the proper function of the jaws. A track wrench should have two heads—one on each end—for several reasons. Almost all track nuts will vary in size slightly, and it is not possible to gage one pair of jaws to fit them all; besides, a wrench works better where it fits the nuts rather loosely. For this reason the jaws on one end should be made to fit the standard nut snugly, and those on the other end should make a loose fit. Such a wrench will answer for all ordinary variations, and it is a much better arrangement than to have single-headed wrenches of two different gages; or, as happens in some cases, to have no wrench at all which will fit nuts which are a little larger or smaller than the standard, or nuts with the corners somewhat worn. Another advantage is that a double-headed wrench can be handled with greater facility. There is an easier bearing for the hands and the wrench is balanced better; for the reason that, while turning on a nut, many turns must usually be given before the nut turns hard enough to require much force at the wrench handle, and hence the double-ended wrench has weight on the swinging end to receive momentum from the applied force and steady the motion of the hands. Any man who has used a double-headed wrench will readily notice how awkward it comes to afterward use a single-headed one. It is quite common practice to make wrenches single-headed and to taper down the last 3 or 4 ins. at the end of the handle to a smaller size, so as to enable it to be thrust through the holes in splice bars to bring them opposite the bolt holes in the rail, in splicing. This form is not a good one, as it makes the wrench too small just where the pressure from the hands comes when the most force has to be exerted; besides, by thrusting the wrench through bolt holes it usually becomes bent and cut about the end, thus rendering it disagreeable to handle. A chisel or pinch point on the end of a wrench is likewise a nuisance.

A track wrench should be straight. A crooked or S-shaped wrench handle is intended for use around machinery, or for catching a nut in close quarters which cannot be reached by a straight wrench, for lack of room. On track bolts, where there is clear space, it is not as serviceable as a straight wrench, for it cannot be so conveniently manipulated. Track wrenches are often made too long, rendering them unwieldy and making it possible to twist off or break bolts without the application of much strength. A wrench for the largest bolts should not be longer than 19 ins. over all. Wrenches wholly of steel can be made considerably lighter than those composed partly of iron, and are better. The usual weight is about 5 lbs. A track-walker's wrench is usually made flat the whole length, and if made of the best cast steel it need not weigh more than 3 lbs. If a wrench is but slightly too loose for the nuts, the jaws may be tightened sufficiently by hammering the shank, cold. Hold the shank of the wrench on the rail, edgewise, and strike it a few smart blows just far enough back on the shank not to bend the jaws. In this way the shank is squeezed and the gage of the jaws tightened without fracturing them. Wrenches should not be permitted to become worn so much that the jaws slip appreciably on the corners of the nuts. Such action is liable to break the wrench and it spoils the nuts, rendering them unfit for further service. When sending a wrench to the shops for regaging, a nut of the proper size should be tied fast to the wrench.

To use a wrench properly one should stand with the toe of the shoe against the bolt head, to hold it, and work with the wrench across the rail, thus affording a rest for the wrench head while catching the nut. If there is anything that is irritating when one is in a hurry it is to have to wait on the awkwardness of a man who will habitually stand on the same side of the rail with the nut in turning it on or off with a wrench, while the bolt is wiggling in its place, there being no rest for the wrench head, so that at each stroke it must be placed on the nut by a special effort with both hands.

Ordinary track wrenches will not fit the nuts of frog bolts, and trackmen often resort to turning them on or off by striking them around with hammer and chisel. Where a considerable number of bolted frogs are in use, wrenches should be had which fit both the nuts and heads of the frog bolts; and where thick beveled washers are not placed under the nut and head, so that they stand out clear from under the head of the rail, the wrenches ought to be of the box pattern.

121. Claw Bars.—A poor claw bar is a provoking thing, because it is wasteful of both time and effort. In order to pull a spike with reasonable rapidity the principal thing to accomplish is to readily get firm hold of it, and the thing of next importance is to be able in the quickest manner to get the spike started; all other objects which might be desired in connection with the pulling of spikes, if combined, are not so essential or important as these two. It is a wrong idea to sacrifice any advantages in these respects, no matter what accomplishments can be had in other ways. After a spike has been started, even as little as $\frac{1}{8}$ in., it can then be easily pulled by almost any kind of a claw bar, because a better hold can be had, and also because the holding power of the spike has been largely reduced. Now in order to get firm hold of a spike readily the claws must be of such shape that they can be shoved straddle the spike and under its head, in a manner not to slip back and let go when force is applied to the bar. Owing to the fact that the fibers of the tie are often broomed about the head of the spike, where the flange of the rail has cut into them, the ends of the claws should be cutting edges about $\frac{5}{8}$ in. wide; not necessarily sharp, but such an edge as can be thrust through or into the wood, so as to get the claws under the head of the spike. Back of the edges the claws should be dished out between and on top, so as to make a sort of notch to hold the head of the spike.

Having thus provided for a firm hold on the spike, the next essential, in order to start it most easily, is all the leverage possible for a proper length of bar. This means a short, thick heel, turning up more or less abruptly, so that, as the bar is revolved on the heel, the leverage will not be decreased by the point of contact moving farther away from the ends of the claws. Now it is clear that the leverage of a claw bar which turns up at the end by a long curve will vary widely with the slant of the bar, depending on how far the spike has been driven into the tie, and the shape of the surface of the tie just back of the spike; and depending somewhat, also, on whether the tie is soft enough to let the bar crush into it. Spikes in soft and springy ties are sometimes as hard to start as in oak, for the reason that the force exerted on the bar crushes or compresses the fulcrum over which it is acting, thus cushioning the blow or force applied, which has the effect of prolonging its time of application, thereby diminishing the intensity of the instantaneous applied force; at the same time it locates the heel farther back on the bar and consequently reduces its leverage. Of course, ties must be taken as they are found; and, consequently in pulling spikes, any drawbacks which arise from the condition of the tie surface can best be overcome by having a bar which as nearly as possible meets the conditions laid down. One other thing besides the firm hold and the leverage aids a great deal in starting a hard-pulling spike, and that is a stiff bar. A bar which will spring considerably when force is applied to it in pulling a spike has its efficiency for pulling reduced in the same manner as when pulling on springy wood; all the force exerted reaches the spike eventually, but the springing of the bar lengthens the time during which the force is applied, and makes of it a less force applied more or less uniformly during several instants or small portions of time, rather than a heavy force, applied instantly (or nearly so); which latter force, of course, has the greater starting effect on the spike.

From experience with many types of claw bars I have concluded that the one which most nearly fulfills the requirements above noted is the old-fashioned straight claw bar, often called the "bull's foot" bar; which term quite nearly expresses the shape of the bar. This bar answers more requirements which determine for speed in pulling spikes than any other with which I am acquainted. No bar as yet devised has been able to answer all the purposes which might be desired for it. The question of a proper form of claw bar is one of great importance, and it has been discussed for a great many years in conventions of track officials. Thousands of men have exercised their ingenuity in trying to design an all-around claw bar, but no change in the "bull's foot" has been made without impairing one or more of its three important features; viz., the readily-griping and firmly-holding claws, the short heel, and the possibility of making the bar stiff. The importance of combining these three features in one bar has in cases been so far overlooked that many worthless products have been turned out. It is no easy matter to properly shape a claw bar, but it is a tool well worthy of considerable attention.

Two objects, especially, men have sought to accomplish in designing claw bars: to pull the spike, either at a single stroke, or, at any rate, without having to place a fulcrum or "bait" under the heel of the bar after the spike has been partly drawn, in order to pull it the remainder of the way out; and to pull the spike all the way out at one stroke without bending it. Neither of these objects has been accomplished by a bar which is equal in efficiency to the plain straight bar. An idea having the first object in view is to place a U-bend in the bar back of the claws, to serve as a fulcrum after the spike has been started. Such a bend introduces the principle of the tuning fork and makes the bar quite springy, unless an amount of metal be placed in the bend such as would make the bar enormously heavy. In one form of claw bar of the "goose-neck" type the U-bend extends backward from the claws, so that in getting hold of the spike the bar must be held in a vertical position, or nearly so, thereby affording the operator no opportunity to throw his weight upon it. Another form of this type quite widely known is the Hamm bar, invented about 1883 by an employee of that name in the service of the Lehigh Valley R. R., where it was first introduced. The method of using the bar is made quite plain in Fig. 294. In the position of the bar at starting the spike the bend is upward. After the spike has been started and pulled part way out the bar is reversed and the pulling is completed by using the bend for a fulcrum.

A long curve at the end of a claw bar has the objection of locating the heel too far away, as heretofore explained, and requires also that the bar at starting the spike must stand nearly perpendicular to the tie, so that the operator must necessarily pull on the bar instead of being able to throw his weight down upon it. A bar having a pointed heel—that is, a heel formed into an edge or corner—will bend a spike while drawing it only part way, because the corner of the heel bites into the tie and holds it (the heel) in one position, so that the head of the spike as it comes out must revolve about the heel as a center, whereas it should move upward in a straight line. A short heel curved properly will turn around just enough in pulling a spike to lift it straight out, as far as the spike can be lifted at each stroke. Figure 296 is about my idea of a properly designed claw bar. The claws, to be strong, must be short without being so blunt that they cannot be readily thrust under the head of the spike; and to hold the head firmly they should be close together; say ⅝ in. for ordinary $^9/_{16}$x$^9/_{16}$-in. spikes. At their extremities, however, the claws should be about $^{11}/_{16}$ or ¾ in. apart, depending a good deal on whether the kind of spike in use is enlarged in the neck. Considerable material must be distributed about the claws and for a foot or so above them, to give strength. The width of the bar, taken just above the claws, should be about 2¾ ins., and the depth through it at the heel, 2⅞ ins. The angle which the main part of the bar makes with the under

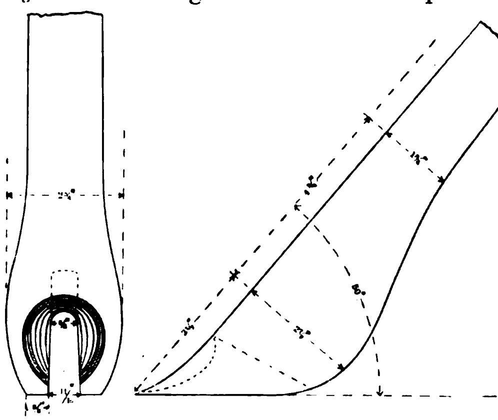


Fig. 296.—Bull's Foot Claw Bar.

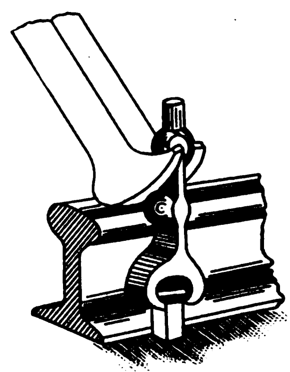


Fig. 297.—Verona Spike Puller.

sides of the claw should be about 50 degrees. From the heel the bar should curve away in cross section to about 1¾ ins. square (corners beveled or rounded off) at 8 or 9 ins. from the claws, and then gradually down to 1⅛ ins. round at the end of the bar. The bar need not be longer than 4 ft. 10 ins. over all—just long enough to reach over the opposite rail when pulling spikes inside the track. A long bar lacks stiffness. The weight of such a bar as is here described is about 30 lbs., which is heavy enough. A short bar of given weight is stronger than a longer one of same weight, and is more easily handled.

It is sometimes the practice to weld cast steel or crucible tool steel claws into an iron or soft steel bar, but it is better to have the claws, heel, and several inches of the bar one piece of steel, if welding of different materials is done at all. In considerable practice the entire bar, including the claws, is made out of soft steel.

Pulling spikes is the hardest kind of work, and the easier one tries to make it the harder does it become. If the spike head is down pretty close to, or against, the face of the tie, or into the broomed edge of the rut cut by the rail flange, turn the bar over and chip away the wood by jabbing into it with the ends of the claws; or, if the spike head and tie face are covered with grease, throw some sand around the spike or crush a pebble or chunk of cinder thereon with the bar. The bar should be grasped with the right hand at about 15 ins. from the claws (right-handed man) and with the left hand near the other end, raised high, so that the bar stands 50 or

60 degrees with the tie face. Then, standing close up to the spike and nearly over it, by a well aimed thrust, drive the claws forcibly straddle the spike and under the head. If the claws are of good steel there need be no fear of breaking them. When a firm hold is had, raise slightly the end of the bar with the left hand, bring the right hand up to the middle of the bar, and, by a quick move, shove the bar down, at the same time throwing considerable weight of the body with the arms. A hard-pulling spike must be started by a heavy, sudden jerk of the bar; it cannot be started easily by a steady push or pull. The operator should always stand over his bar. One cannot exert much force, nor do it so easily, by pulling down on the end of the bar; besides, if the bar slips or the spike head breaks off the operator is liable to take a tumble, with the bar on top of him. After the spike is started, give the bar a push or two and, when within a foot or so of the ground, push it farther down by stepping on it with the foot at about the middle of the bar, throwing the weight of the body thereon. A straight bar will not pull a spike more than half way out at one stroke, and if the tie is quite solid another stroke must be taken, using a fulcrum or "bait." In old ties, however, the spike may usually be pulled at one stroke. After the spike has been pulled as far as it can be at a single stroke, hold the bar at an angle of about 30 degrees with the tie, suddenly jerk the claws up against the head, and in three cases out of four the spike will come out; or, if pulling outside the rail at a place where the ballast is not filled in against the ends of the ties level with the tops, after the spike is started shove the bar down forcibly, catch it with the foot and keep it going right on down over the end of the tie, and generally the spike will fly into the air. One need not be a bit timid as to how he uses a well-made claw bar so long as he uses it for no other purpose than that of pulling spikes.

Now in pulling spikes with such a bar—that is, a straight bar—there is no need of bending the spikes. If the spikes pull hard all the way out, a stone or block of wood about 2 ins. thick should be used for a fulcrum; and, by catching the spike head, after it has been started, with the ends of the claws in line with the body of the spike instead of shoving the claws under the head so far that they take hold at the point of the head, the spike can be pulled straight out in two strokes. There is no need of having an extra man along to hold a spike hammer or pick for a fulcrum. A lively man can raise the bar with one hand while he places the fulcrum under with the other; but, as stated, in three cases out of four, while pulling spikes from ordinary ties, he will need no fulcrum. An aid in starting spikes in sound, oak ties, or in freezing weather, is to give the spike a slight tap down with a hammer, before attempting to pull. It is almost painful to witness the contortions of some men in pulling spikes. Men green at the business usually waste much strength, unless well instructed, and lazy men are liable to get their necks unjointed. The latter invariably go about the work as though the claw bar was the thing at fault instead of themselves. Wherever one sees two men pulling on one claw bar, or a man holding the bar while another is pounding the heel with a hammer to drive the claws under the head of the spike, it is a pretty sure indication that either a different kind of bar is needed or a different kind of man.

Where there is not room to use a claw bar, as, for instance, behind guard rails, spikes may be pulled by a sharp pinch bar, the spike being started by thrusting the point of the bar under the head of the spike. Such, however, is a slow and tedious operation. A special tool for griping the heads of spikes behind guard rails, or in other places where there is not sufficient room to use a claw bar, is made by the Verona Tool Company. It is used in connection with an ordinary claw bar, and is a labor-saving device.

It consists of a single straight piece of steel about 9½ ins. long, formed into solid jaws on one end for griping the spike head, and into two knots or bulges at and near the other end for engaging with the claw bar. When pulling the spike the claw bar rests on the top of the rail, as in Fig. 297. The stem is 1 in.x½ in. in section, the jaws ⅝ in. thick and the opening of the jaws ¾ in. It is simple and light, not being much larger than a track spike, and no section crew should be without one. For elevated roads, where guard rails or guard timbers are usually close to the rail, a special form of bar for pulling spikes is generally used. The Manhattan Elevated Ry., of New York, uses a bar with a curved foot, to the end of which there is hinged a shackle with solid jaws to catch the head of the spike. The curved foot rests on the rail, while the spikes are being pulled. The arrangement works in a manner similar to the use of the Verona device with a claw bar, except that the stem of the jaws is hinged to the bar instead of fitting in between the claws.

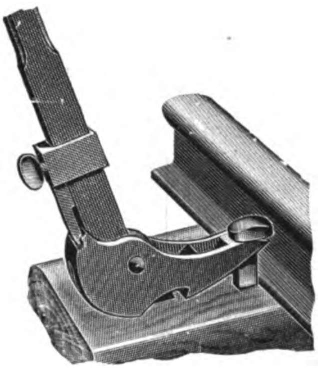


Fig. 298.

Fig. 299.

A form of shackle bar in common use for pulling drift bolts in bridge work is an ordinary pinch bar with a hinged shackle near the point, as in Engraving *H*, Fig. 309, the bar taking hold by slipping the shackle over the end of the bolt and placing a fulcrum under the heel of the bar. A shackle bar known as the Lewis "drift bolt and spike puller" is shown in Figs. 298 and 299. It takes the form of a heavy pinch bar, with a hinged foot or shackle, and a sleeve which slides along the bar and regulates the operation of the shackle in connection with the bar proper. In Fig. 298 the device is displayed as a spike puller or claw bar. The length of the shackle is such that it may be thrust between the rail and guard timber or guard rail and engage the spike without such interference as is experienced with the ordinary claw bar. By setting the sleeve thumb screw the shackle is held rigidly immovable with the bar proper. By loosening the sleeve and tilting the bar forward, with the shackle in the position shown in Fig. 299, the sleeve may be slipped farther down on the bar, so as to hold the bar at a new inclination with the shackle—that is, the inclination is changed from an obtuse to an acute angle. By this arrangement the bar is permitted a wider range of movement in front of the guard timber or guard rail. Figure 299 displays the arrangement of the parts for pulling drift bolts. The sleeve is moved upward on the bar and clamped in a position which holds it clear of the shackle. The drift bolt or other rod is then engaged between the point of the bar proper and an inner edge of the shackle, in a clutch-like manner. The device will pull a nail of any size, track spike, ship spike, bridge or drift bolt, with or without head. The length of the bar is 4 ft. 6 ins. and the weight 28 to 30 lbs. The Mogul spike and drift bolt puller, shown as Engraving *M*, Fig. 295, consists of a pair of jaws hinged to a head to which is pivoted a bar with a heavy lug which wedges between the jaws at the back and forces them tightly together at the pulling side when force is exerted on the bar. The jaws are the fulcrum of the bar. It is intended for use in pulling track spikes, drift bolts, boat spikes from crossing plank or track spikes without heads. By letting go of a spike that has been pulled part way out and raising the bar a new hold can be taken on the spike lower down, so that by repeating the process the spike can be pulled straight up. It is drop-forged from steel and is 5 ft. long.

122. Pinch Bars.—The working end of a bar, whether it be drawn to an apex or to an edge, is known as the "point." Plain, straight bars are pointed in several ways, each kind of bar taking its name from the way it is pointed. A wedge-pointed bar is generally known as a "crow bar;" and a bar with a common chisel point, a track "pinch bar"—as distinguished from another form of pinch bar which has both a round end and a sharp edge or heel, used exclusively for "pinching" or starting cars. A diamond-pointed bar—that is, one the end of which is drawn to an apex, like a right pyramid, so that the apex is on the axis of the bar—is called a "bridge" or "timber" bar; if the end of the bar is formed as an oblique pyramid, so that the apex or point lies in the plane of one of the sides of the bar, it is called (but for no special reason) a "lining" bar. To make these descriptions entirely clear, perspective and end views of each kind of bar are shown in Fig. 300.

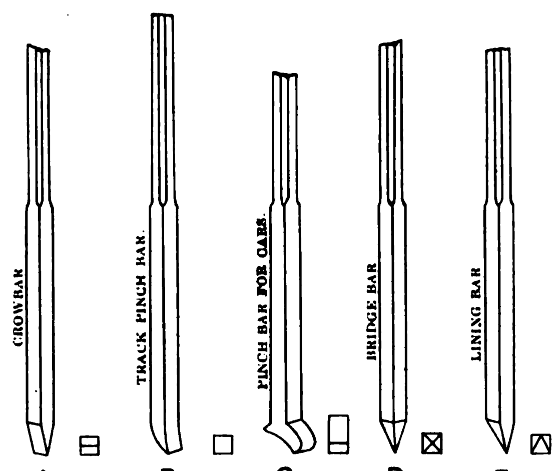


Fig. 300.—Various Ways of Pointing Bars.

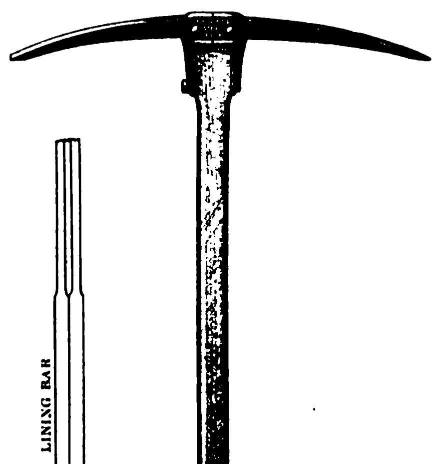


Fig. 301.—Eyeless Pick.

In track work a lever or plain bar of proper form answers a great variety of purposes. There is scarcely any piece of work undertaken where such a tool is not needed. The form of bar which gives best satisfaction is the pinch bar. The question of a proper form of point for bars used in track work is of the highest importance, and expensive track work is often chargeable to ignorance of this fact. As proof that such ignorance prevails to some extent, one may sometimes see trackmen working with crow bars. Now a crow bar, as such, is of no special use in track work, and the only use for it anywhere is for jabbing holes into the ground for driving fence posts. A crow bar can be used in lining, but for any other purpose on track it is indeed an irritating thing. It has been so customary with many to use the term "lining" bar for any kind of bar used as a lever in throwing or lining track, whether it be a crow bar, pinch bar, or other, that it is not generally understood by the term just what kind of bar is really meant. The term is not particularly significant when applied to any special form of bar, but the pinch bar is the best for lining track, on account of the bearing surface it presents at its extreme end when prying against the ground or the ballast—which is important in throwing track. A crow bar used flatwise the point gives the same bearing, but its tendency is to slip back, whereas a pinch bar tends to catch and hold when the prying force is exerted. Some prefer a bar like that shown as Engraving *E*, Fig. 300, because it can be poked through the ballast easily. Such advantage, however, is unimportant, for there is no difficulty in this respect with a pinch bar kept reasonably sharp. If there was any material advantage to be gained in this respect, a point like that shown at *D* would be superior to any; but either are poor points for holding against any ballast except broken stone. A bar for nipping or pinching rail, ties, etc., is in continual demand, is indispensable, and none but the pinch bar so well answers such purposes. It is an easy matter to keep its point in working condition, because it is broad and strong, whereas a point like that shown at *E* would soon break off while nipping or prying under rails, and thus render the bar worthless for this purpose until repaired. As, in any case, it would be impracticable to have differently pointed bars for all the different uses, it is fortunate that the pinch bar answers best for each and every one of them; and none other should therefore be used.

The pinch bar should be as light as is consistent with strength. As it is a tool which must be picked up frequently and swung around and handled quickly, any excess in length makes it cumbersome, and besides, the longer the bar the larger must it be made in cross section in order to withstand bending in service. Four feet 9 ins. is about the length at which a bar can be made stiff enough to withstand all one man can exert in throwing track, and at the same time be not too heavy to handle for other purposes. A bar of this length should weigh about 20 lbs. Beginning at the point it should be $1\frac{1}{4}$ ins. square for about 16 ins., $1\frac{1}{8}$ ins. octagon for 16 ins. more, and taper off to $1^1/_{16}$ ins. round in the remaining 25 ins. One can accomplish more with a bar of this length and weight than with a longer one weighing 25 to 30 lbs. The difference becomes very appreciable where a man has to carry a bar for several hours, and swing and thrust with it, as in lining track, or even to pick it up quickly for a moment's use every little while, as when laying a turnout, or while using it in tie renewals, etc. It is a mistake to make a bar heavy at one end and taper it off to $\frac{7}{8}$ in. or smaller at the other. There are several reasons for this. In the first place, anything less than 1 in. in diameter is too small to grasp in the hand and agreeably exert strength against. A man will unconsciously lift most on the bar which gives his fingers the most comfortable hold. If the end of the bar is small enough, it will be used in the bolt holes in rails and become badly cut, in time, and thus rendered disagreeable to handle. Too much weight at one end makes a bar unhandy to pick up and swing around at light work. Moreover, in lining track where the ballast is soft and the bar is thrust far in, it will be bent near the middle, if light at this point. While the distribution of metal in one end of the bar should be something more than at the other end, it should not, for the reasons stated, greatly preponderate over the weight at the middle. The bar which can be handled with greatest facility is the one which most nearly balances in the hand when picked up at or near the middle. Another mistake sometimes made is to point both ends of the bar; and the same applies also to pointing the ends of claw bars (sometimes done for chipping wood from around the heads of spikes) and tamping bars. For handling timber, both ends of a bar should be pointed, one end having a long or sharp diamond point, but in track work there is but little or no use for such, and it is actually detrimental to the serviceableness of the bar. Men will handle somewhat timorously any tool which has a sharp point or edge continually pointing toward them. The end of a pinch bar, tamping bar or claw bar which is uppermost, in ordinary usage should be nicely rounded off, so as not to be unpleasant to grasp. Men who have not handled these tools much might think such matters of little account.

Solid steel pinch bars are best, but if the bar is made of iron it should have a hard steel point or tip welded on. The point should be very slightly turned up, and its length should be about 1¾ times the thickness of the bar. Iron bars are easiest repaired, when broken. A very good pinch bar is made by cutting off to right length, and pointing, a piece of octagon steel bar of 1⅛ inches short diameter. While not quite as stiff as a bar having the same amount of metal distributed as above described, so that one end of the bar is heavier than the other, and of square cross section, it is quite stiff enough, and is more agreeable to handle than any other bar; besides, it is not far from the right weight (16 lbs.), and it is cheap. Many prefer this kind of bar to any other.

One of the best tests of the worth of a trackman is to observe how he handles himself when using a pinch bar. It is a tool with which much can be made to move if one uses it easily and with intelligence. Some men, if about to lift a rail slightly, will persistently attempt to pry it loose from the tie to which it is spiked, instead of nipping it upon a tie which is not spiked; and such men as are in the habit of lifting ties by prying over a fulcrum which is 12 to 18 ins. or farther from the end of the bar, or who will attempt to raise track by taking a "lubber lift" under the rail, should be taught (if possible) the simple principles of the lever.

123. Tamping Bars.—The tamping bar is frequently made too heavy. It should not weigh more than 10 lbs., and it should not be longer than 5 ft. 3 ins. over all. The handle should not be more than ¾ in. in diameter; if of steel it need not be more than $^{11}/_{16}$ in. diameter. Soft steel is the best material. A bar of the latter size is more severe on the hands than one of larger diameter, but this is easily remedied by holding a piece of leather in the hand which grasps the end of the bar. As tamping is very severe on the hands, anyhow, until after one's hands become very callous, many use a glove or piece of leather on one hand at all times, with any size of handle. A very good arrangement for making the bar easier on the hands is an enlargement of the handle at the end, the end being formed by welding on a 6-in. piece of 1-in. pipe, plugged at the end, thus making the bar of agreeable size where it is grasped, without adding appreciably to the weight of the bar. The pan or tamping head of the bar should be steel, about 3½ ins. long, 3½ ins. wide and ½ in. thick. Where the track is old and the bed hard, having been well kept up, so that the lift when tamping is small, the pan should be drawn down to ⅜ in. on the striking edge; for new track the thickness should be ½ or ⅝ in. The handle should be straight, except near the pan, where it should be reversely crooked, so that a man may stand nearly erect, with his feet between the ties, and, by swinging the bar at arm's length, the arms hanging downward, be able to drive the pan of the bar under the tie horizontally. The pan ought to make an angle of about 35 degrees with the direction of the handle. The flattening of the end of the tamping bar handle into a spade for removing ballast from the side of the tie is not approvable. In compacted gravel or other ballast such an arrangement amounts to but little or nothing, and in any kind of ballast the pick is a superior tool for this purpose, as heretofore stated. A handle of such form is also worked with less facility and comfort.

The knack of working a tamping bar with ease and effect is to let it swing at arm's length, as stated above, and not to strike with it as one would handle a spear in spearing fish; at the same time it should be given force by raising it vertically, as it is withdrawn, and allowing it to fall as it swings toward the tie. The practice of holding a tamping bar in front of the chest and striking with it from the shoulder is very tiresome. Rapidity in tamping depends on the gait rather than upon the force of the blow, altogether, and for this reason the bar should not be as heavy as some make it. Any man who will order a tamping bar made with a handle ⅞ in. in diameter and a head 4 ins. wide, the tool weighing 12 or 13 lbs., if obliged to use it, would certainly change his mind. In order that the work may be effectively done, the ballast between the ties, when tamping, should be kept at least as high as the lower edge of the tie, in order to form a backing to hold in the material which has been hardened. Tamping bar handles should be kept clean and free from abrasions. Rust can be quickly removed from the handle by drawing it a few times back and forth through a heap of gravel or cinders. To keep the handle from heating to an uncomfortable temperature while not in use, as during the noon hour on hot days, it may be run into the ground or into a heap of ballast.

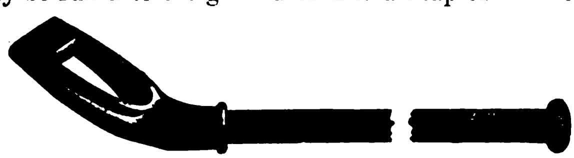


Fig. 302.—Jackson Tamping Bar for Dirt Ballast.

Tamping bars with wooden handles are used to some extent. The Hoxie patent tamping bar has a wooden handle about the size of a pitchfork handle, and the tamping part is made of cast steel with a socket, into which the wooden handle is fitted. It is so heavy and clumsy, however, that it is not as desirable to use as a bar with a smaller iron handle made all in one piece in the usual way. The Jackson tamping bar (Fig. 302) has a gas pipe handle combined with a malleable tamper, with the intention of securing strength and rigidity without excessive weight. The tamping head is an adaptation of the special shape in the Jackson tamping handle tip for shovels (Fig. 293). In dirt or sand ballast a bar of this kind ought to do good service. A tool called a "puddle" is sometimes used for tamping gravel, cinders, dirt ballast, or sand. It is essentially a tamping pick with the pick end of the tool cut off near the eye. There is really but little or no demand for a tool of this kind, because the tamping bar or shovel is better adapted for tamping in all kinds of ballast except broken stone or slag, in which materials the tamping pick is used to best effect.

124. Chisels.—A track chisel, or track cold chisel, when new, should be about 8 ins. long, so that there may be plenty of material to work upon as the tool becomes blunted and wears away. The center of the eye should be about 3 ins. from the striking face, and the eye should be punched squarely through the chisel. The head or upper portion should be about 1½ ins. square, in cross section, with corners beveled and tapered toward the top, and the cutting edge about 1⅜ ins. long. The chisel is made wholly of tool steel and its weight is 3¾ to 4½ lbs: a bar 1½x1½x6 ins. will make one. Much care is needed in tempering, so as to get the metal hard enough, and still not so hard as to be brittle. The edge or cutting end should be sharp, but rather bluntly drawn out; a chisel drawn out thinly near the edge will easily fracture. In using a chisel for the first time after sharpening, it is well to play lightly upon it for a few blows. In frosty weather the chisel should be warmed over a fire before using. Chisels cut faster and last longer if a little oil is applied while the rail is being cut. Chisels which become dulled without fracturing or breaking away at the edge may be sharpened on the grindstone for a few times, or until the end becomes so blunt as to require drawing out. In repairing chisels both ends should receive attention, for frequently the striking face will need truing. Many a man has lost an eye in being struck by a flying piece of steel from a track chisel, and danger of this kind is always greatest where the striking face of the chisel is in a battered or ragged condition. Steel is not so liable to fly from a chisel that is being struck by a sledge hammer as from one struck by a spike hammer, because the face of the sledge is large enough to more than cover the face of the chisel; and, being large, is not so liable to miss or make a glancing blow. Old hammer handles cut into pieces 12 or 15 ins. long make good handles for chisels. It is important that the eyes of track chisels should be uniform, so that the same handle will fit them all. The handle should fit the chisel just snugly enough to hold it steady while being struck, but not tightly. A handle that is driven in tightly will sting the holder's hands every time the chisel head is struck an unfair blow.

125. Rail Saws.—On certain occasions there is no more convenient or cheaper method of cutting rails than with a hack saw. In order to cut a rail with the chisel it is necessary to first take the rail out, if it be in the track, while with the hack saw this need not be done. And then, about the shortest piece that can be cut from the end of a rail successfully with hammer and chisel is 3 ins., whereas with the hack saw a piece of any length from $\frac{1}{8}$ in. up may be taken off. It frequently occurs, therefore, that the use of the hack saw can save the expense, waste and inconvenience of having to cut two rails in order to fill a gap a little shorter than the standard rail length. Thus, for instance, in case a piece of rail 29 ft. 10 ins. long was required, most trackmen, if provided with no other cutting tool than the chisel, would use two pieces of about a half rail's length each, making a cut for each or perhaps utilizing a piece already on hand and making a cut for the other. For want of a convenient means of cutting off very short pieces of rail (1 to 3 ins.) foremen will sometimes back the adjacent rails into the joint openings to gain space, so as to use a whole rail and avoid the cut; but since such practice interferes with the allowance for expansion it is not approvable.

The hack saw (*C*, Fig 309) consists of a small toothed blade of hard steel fitted into an adjustable frame resembling the frame of a meat saw. Ten inches is a common length of blade, but for cutting rails heavier than 60 lbs. per yd, the length should be 12 ins. The blades cost but a few cents each, and if carefully used a single blade will make an entire cut. Water is the best lubricant to use on the saw while cutting. For use at stub switches, when moving rails run tight, it is exceedingly serviceable. A small piece may be cut off the end of a rail, in place in the track, in a few minutes, without obstructing the track, and one man can do the work. No section having stub switches should be without hack saws.

Portable rail-sawing machines operated by hand are being extensively used. The Bryant rail saw is shown in Fig. 303. The circular saw is hollow ground and is turned by gearing which drives a sprocket wheel engaging with the back sides of the teeth. Two men are required to turn the cranks. The frame of the machine is clamped to the rail by adjustable jaws and the saw is fed into the rail automatically. The machine is made in different sizes, the diameter of the saw ranging from 16 to $20\frac{1}{2}$ ins. and the weight of the machine from 250 to 285 lbs. The frame is revolvable on its vertical axis, so that both square and miter cuttings can be made. The lubricant for the saw is a thin oil, which drips from a pot provided with a faucet, as shown. A fair estimate of the time required to cut a rail with this machine is stated to be (in minutes) the weight of the rail in pounds per yard divided by five, or 15 minutes for a 75-lb. rail. Each machine is provided with a small grinding attachment for sharpening the teeth. In the Smith portable rail saw (Fig. 304) the blade has a pendulum movement and is operated by two levers, like a hand car. The frame of the machine is clamped to the rail by the revolving wedge *A*, the bolt *B* and a sliding hook. The saw can be quickly raised or lowered by the hand-wheel, but, when cutting, it is fed automatically. The saw is kept taut or rigid in the swinging frame by the straining nut *E*. Soap-suds is the lubricant used. The weight of the machine is 120 lbs.

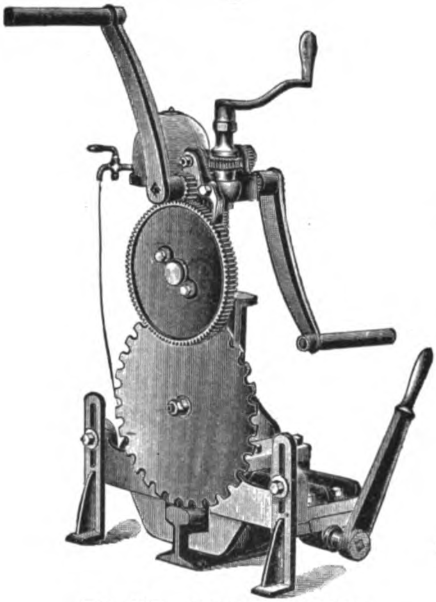


Fig. 303.—Bryant Rail Saw.

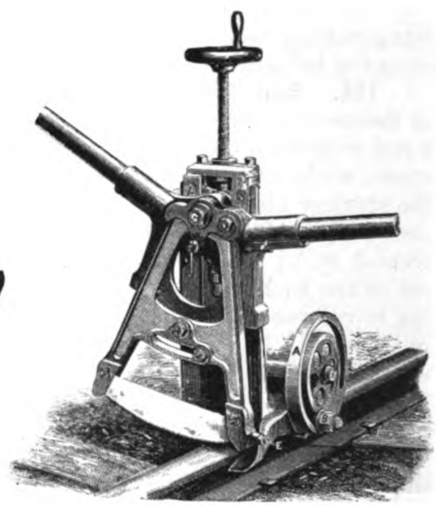


Fig. 304.—Smith Rail Saw.

For cutting rails at a skew, as at miter joints, some kind of rail saw is needed; otherwise the joint at the cut end of each piece of rail used in the track must be squarely cut, which makes it necessary to cut off the skew end of the whole rail meeting at such a joint—or two cuts for one, in many cases. On some roads where skew joints are used it is the practice to make square cuts when laying pieces of rail, while on others a rail saw is used to cut the rail at the proper angle to match with the skew or miter end of the rail that is not cut. Rail-cutting machines are rather too costly to be furnished each section, and, besides, they require more careful handling than track tools usually get. It is advisable, however, to have one or more of these machines on hand at the headquarters of each division, to be sent to points where a good deal of turnout laying or other work involving rail cutting is to be done, and to furnish one to each yard section crew, floating gang and wrecking car.

126. The Gage.—For general purposes the ordinary plain wooden gage with metal lugs is the best. A piece of $1\frac{1}{2}$x2-in. seasoned ash shod with cast iron or brass end lugs, set into the wood their thickness and well screwed fast, is about the proper thing. It should be handled with more care than iron tools usually get, and should be frequently tested. For

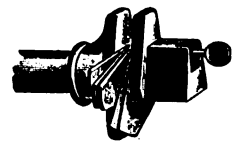


Fig. 305.—McHenry Adjustable Track Gage. **Fig. 306.**

this purpose two metallic lugs or blocks of wood may be screwed fast to a board on the side of the tool house, inside, at proper distance apart, where they are not liable to be disturbed, to serve as a gage tester. A gage tester used on the Michigan Central R. R. is a piece of rail about 6 ft. long with the head taken out between two saw cuts 4 ft. $8\frac{1}{2}$ins. apart.

A piece of $1\frac{1}{4}$-in. iron pipe with two lugs welded on makes a durable gage. In one form of iron or steel pipe gage each end of the pipe is shrunk upon an iron plug which projects beyond the pipe and carries the gaging lug. The change in length of such a gage between 40° F. below zero and 150° F. above, is only about .07 in. At either of these extremes the variation in length from that at average temperature would then be only about .035 in. It is somewhat heavier than a wooden gage, but not so liable to be broken or get out of adjustment. In another form the piece of pipe or cross bar is screwed into malleable end pieces forming the lugs. No form of all-metal gage can be used on track divided into insulated sections for block signal service, since it completes the electrical circuit between opposite rails, the same as a car axle. To interrupt the metallic connection between the rails the continuity of the metal is broken by a piece of wood spliced to the two parts forming the cross bar of the gage. One tool of this kind is the Sheffield pressed steel insulated gage of inverted U-section, illustrated by Fig. 323. The tool is pressed from a single sheet of steel and is light and strong. The central open part or cross bar of the gage is filled with wood, thus materially strengthening it without adding more than a trifle to its weight.

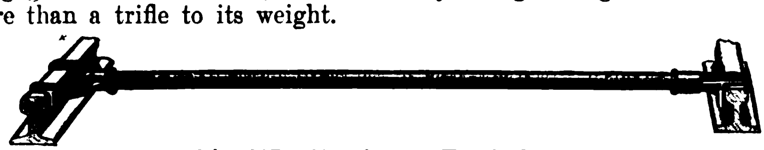


Fig. 307.—Huntington Track Gage.

For convenience and accuracy in gaging curves of widened gage, tool is sometimes provided with an adjustable end, which can be set to measure any desired gage within the limits of widening. A tool of this kind should be used only on curves, if used at all, since the adjustable feature involves the work in risk of mistake. It would therefore seem preferable to use a gage the lugs of which are rigidly set to the standard measure for straight line, and for widened gage on curves to use a shim of proper thickness in connection with the standard gage. On the Atchison, Topeka & Santa Fe Ry. gages with adjustable ends for use on curves are painted red, as a distinguishing mark to remind the foreman of the necessity of looking carefully to the proper adjustment of the tool for the curve on which it is being used. An adjustable gage designed by Mr. E. H. McHenry, when chief engineer of the Northern Pacific Ry., is provided at one end with steel shims, each $\frac{1}{8}$ in. thick, which are revolvable about the axis of the gage, but in standard-gage work are turned up out of the way and clamped to place in a fixed position, by a thumb-screw, as shown in Fig. 305. When it is desired to widen the gage, the proper number of shims to adjust for the required amount of widening are turned down in front of the gaging lug and clamped to place. In the practice of one road where this gage is used on curves, one shim is turned down for each increase in curvature of 3 deg., and the five shims provided allow gaging for all curves up to 15 deg. On easement curves an additional shim is turned down for each 3 deg. of curvature progressively, until the full maximum is reached. An enlarged view of the adjustable end is shown as Fig. 306. The late Mr. Richard Caffrey, of the Lehigh Valley R. R., was the designer of a gage on which one of the lugs is of proper thickness (1¾ ins.) to fit the flangeway of guard rails. In other words, the outer side of the lug is for gaging the running rail and the inner side for gaging the guard rail.

Some trackmen believe that much error creeps into the work of gaging through carelessness in not placing the gage squarely across the rails. With this idea in mind Mr. William S. Huntington many years ago devised a gage with a T-end, shown in Fig. 307. This is sometimes called the "horned" gage, and the device is in quite general use. The two lugs on the forked end are about 6 or 8 ins. apart, and it is generally supposed that in using it men will readily place the gage so that both lugs touch the rail, thus insuring that the cross bar of the gage is set squarely across the track. In my experience I have found such not to be the case, and I regard a gage of this form as a good deal of a nuisance. In the first place, a man who tries to be especially careful in placing the gage on the rails will waste several seconds swinging the gaging end of the tool slightly to and fro to see if both lugs on the other end of the gage are touching the rail; and then, three times out of four the gage will be brought to rest with only one lug touching. Men who do not resort to such "fussing" will seldom

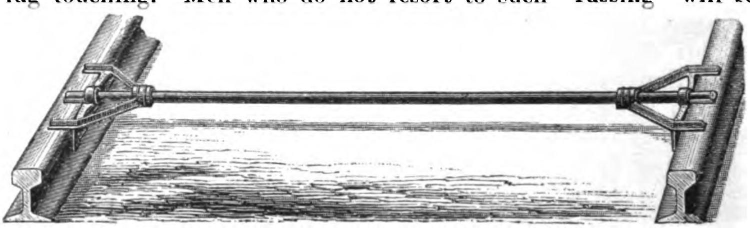


Fig. 308.—Warren Circular-End Track Gage.

get both lugs on the forked end of the gage in touch with the rail. The trouble arises from the circumstance that the T-end of the gage is entirely too short in proportion to the length of the cross bar. In the second place, it should be noted that a careless use of a gage of this form involves the work in greater error than is liable to ensue from the careless use of a straight gage. In swinging a straight gage out of the square or perpendicular position the tool revolves about one end of the cross bar and the error in measurement is a decrease in gage amounting to the versed sine of the arc moved through. In a like movement through a small arc with one end of a Huntington gage, however, the error in measurement is always an increase in gage, because the tool does not swing about one end of the cross bar, but at one extremity of the T-end—that is, at one or the other of the two lugs, thus virtually changing the form of the gage from a "T" to an "L." It will be readily seen how a slight movement of this gage out of the perpendicular position will throw the gaging end out of gage much faster than will a like movement with a straight gage. In other words, if both lugs of the forked end do not coincide with the gage line of the rail, the true length of the gage is not interposed between the rails, but a greater length. Notwithstanding that the Huntington gage is in much favor, the truth of the above statement is, I think, easily demonstrable to the satisfaction of any person who will observe carefully the manner in which the tool is usually handled in actual practice. A committee of the Roadmasters' Association of America, in 1895, reported unfavorably on a gage with a forked end.

It is a very easy matter to place a straight gage on the rails closely enough to the perpendicular position for all practical purposes; and men exercising only ordinary care will do it without loss of time. Men who are inclined to be careless will not do as good work with the Huntington gage as they will with a straight gage. Coming down to fine points, the only gage which eliminates the errors of handling is the Warren tool, shown in Fig. 308. The ends or gaging lugs of this tool are formed as arcs of a circle, of which the diameter is the required gage of the track. By this form of construction the proper gage distance is always had whenever the circular lugs are in contact with both rails, whether the gage is applied to the rails squarely or obliquely. If a circular lug is used on only one end of the gage the curvature of the same should conform to an arc of radius equal to the gage of the track. The same degree of accuracy may be had with the straight gage by swinging one end so as to get the maximum measurement between the rails, which is, of course, the perpendicular distance. Many trackmen make a practice of doing this, and for sake of the moral effect it is to be recommended. For practical use the straight gage is reliable enough, and it lends itself to rapidity of movement better than any other. Gages with segmental or forked ends are somewhat cumbersome and require too much manipulation. The practice of combining a level bubble with a track gage is carrying refinements rather too far, as the usage of a gage is too rough for a level.

For T-rails the lugs on a gage should be deep enough to reach below the rounded corner of the rail head. The question of gage measurement

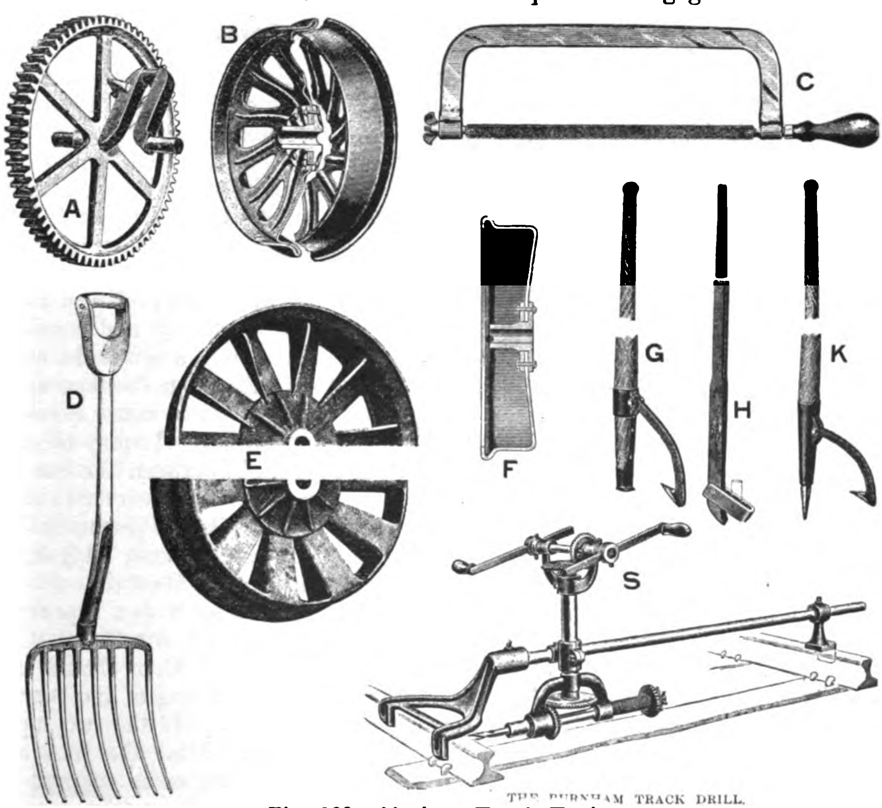


Fig. 309.—Various Track Tools.

between rails having heads with sloping sides is discussed in connection with the subject of rail design (§6, Chap. II). Gages used in street railway work, on girder rails, should have short lugs which will not quite reach the tram. If the lugs are too long they interfere with placing the gage on the top of the rail head, and as a consequence the lug will touch at a point somewhere on the fillet between head and tram. The middle point of a gage should be marked by a tack or notch, for use in throwing track to center. In using a gage of any form trackmen should be careful not to let the rail spring in against the lugs, as in this way the lugs are liable to be loosened or bent.

127. Level Boards.—A level board should be made of a strip of well seasoned white pine, or other soft, light wood, $1\frac{1}{4}$ or $1\frac{1}{2}$ ins. thick. Soft wood is better than hard wood for the purpose, because it forms a better cushion to protect ths spirit tube from hard jarring when the board is set down or falls over on its side. As a means of setting the board for curve elevation the best arrangement is to notch one end of the board into steps. These steps usually rise by increments of $\frac{1}{2}$ in., but sometimes the increment is made $\frac{1}{4}$ in. In the former case the length of the step is usually made 3 ins. and in the latter case $1\frac{1}{2}$ ins. For roads or sections where

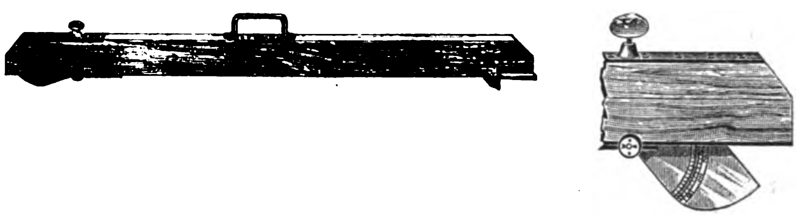


Fig. 310.—McHenry Involute Track Level.

the curves are easy the board need not be notched higher than 4 ins.; but if the curves are sharp the notching should provide for an elevation of 5 ins., or as much higher as is practiced on the particular road. After the board is notched a hand-hole should be cut in such position that the board will balance when carried. An iron handle adds weight to the board, makes it top-heavy, and is always in the way, either to be caught by something and wrenched off or loosened or to be held down by other tools when carried on the hand car; if placed over the spirit tube it obstructs the view to the same. It is a bothersome appendage and not necessarily of any use. The spirit level should be fairly sensitive, responding quickly and considerably at a $\frac{1}{4}$ in. lift in the rail, but of course it need not, and should not, be of the finest grade—that is, one which responds with great freedom and quickness. On the other hand, a sluggish bubble is liable to cause considerable variation in the elevation, and bad work generally. It may be set at any point along the top of the board, but preferably between the hand-hole and the notched end, so as to come under the eye of the observer as the board is set down; for when placing the board on the rails the person holding the board will necessarily be looking toward the notched end. A guard plate set into the board its thickness should be placed over the tube.

It is, of course, an easy matter to set a spirit tube if two supports known to be level are at hand. The tube is simply pressed into the plastic plaster of Paris until the bubble stands at the center. Care should be taken to get the tube parallel with the board, else any leaning of the board out of the vertical will affect the showing of the bubble. If the two supports are not level (but they should be nearly so), adjust the tube so that the bubble remains on one side—that is, toward the same support—and the same distance from the center mark, upon reversing the board.

Then by changing one of the supports, so as to bring the bubble to center, it (the bubble) should remain there upon reversing the board. This done, a coat of oil or varnish should be given the board and, to facilitate finding the right notch, as well as a means of guarding against the use of the wrong notch, in any case, the notches should be numbered on both sides of the board, by integers, as in Fig. 339(A), or every notch, if desired. For the purpose of lightening the board it is the practice with some roads to take out portions of the interior, making two or three openings through the board a foot or so in length and 3 or 4 ins. wide. On some roads very careful preparation is made to facilitate precision of work in setting level tubes. Thus, for instance, the Chicago, Burlington & Quincy Ry. has provided for the purpose, in its shops at West Burlington, Ia., two masonry piers with stone caps, set at the proper distance apart, and steel plates are set in the caps and precisely leveled by scientific methods. All level boards repaired or sent out from the shop are adjusted to perfect level, but as a means of preventing errors which might arise from the absorption of moisture, the board is first boiled in oil before the abjustment is made. The rules of the New York Central & Hudson River R. R. require that during the month of December each year track levels shall be sent to the supervisor for adjustment. They are then painted a color (the same color as tested track gages) to indicate that they have been tested at headquarters.

Instead of a notched level board some use a plain rectangular board about 5 ft. long and 3 or 4 ins. wide, in connection with a "curve block." The latter is simply a piece of board of same thickness as the level board, about 2 ft. long and of proper width, notched or stepped for various amounts of elevation. In using this block, it is, obviously, placed under the level board, and on the inner rail of the curve. If the level board or curve block is notched only to the half inch and it is desired to work to the quarter inch, a shim of ¼ in. thickness is carried in the pocket to give the half step, in case of need. Some disapprove of a notched arrangement of any kind, from fear that error in the work might arise from the use of a wrong notch. A very common substitute for the notched level board is one having an elevation bar sliding vertically in guides in one end of the board and adjustable by means of a thumb-screw. The elevation bar is usually a strip of brass, graduated and provided at the foot with a base plate about 6 ins. long, set at right angles to the board to support it laterally and prevent it from falling over sidewise. In some cases this base plate is flanged, so that it will not slip off the rail. In the use of this form of level board there is, of course, the advantage that the manipulation for the proper elevation is done once for all, in any piece of work, but there is also the disadvantage that when wanted for use the elevation bar will sometimes be found bent or the thumb-screw lost; whereas, in the use of the notched board there is nothing, aside from the spirit level, to get out of order.

Figure 310 shows the "Involute" level, designed by Mr. E. H. McHenry when chief engineer of the Northern Pacific Ry. The desired amount of elevation is secured by means of a plate of hardened tool steel ground to an involute curve and fitted into a slot at one end of the level, as shown by the enlarged end view. The plate is curved in such a way as to touch the rail always at the lowest point as it is drawn out, while the contact with the rail at the other end of the level is maintained stationary by a gage lug. In connection with the gage lug there is also a base plate somewhat wider than the thickness of the level board, to prevent the board from falling over sidewise. The curved plate is graduated both sides for various amounts of elevation up to 6 ins., and is held to the position in which it is set, by a thumb-screw. The "Duplex" level board (Fig. 311) has two spirit tubes—one fixed in the board, and a supplementary level attached to a steel plate "level bar" or movable indicator arm pivoted to the middle of the board at the side and swinging against a graduated arc. The length of the indicator arm is equal to half the distance between the rail centers, carries a pointer at the end and can be clamped to place by a thumb-nut. For use on curves the arm is set at the proper elevation for the outside rail, which is then raised until the bubble indicates the level position. By placing the board across the rails and moving the indicator arm until the bubble in the attached tube comes to center, the amount by which the track is out of level is measured or shown on the scale.

Many trackmen and others have turned their attention to a combination level board and gage, quite unmindful of the fact that these two tools are seldom or never used simultaneously or on the same piece of work. The jarring to which a gage is subjected would soon "paralyze" the spirit tube of a level board and throw it out of adjustment; and moreover, the combination tool is necessarily heavier than either ought to be, which means, of course, less speed in the work. There are many contrivances of this kind, some finished off in grand style, at handsome cost, but all to no worthy purpose. Trackmen should not attempt to work with pocket level and straightedge, because the level, being applied to only a very short length of straightedge, will be thrown badly off by any unevenness in the upper surface or edge of the same, or if placed oblique to the straightedge in the least. A carpenter's level does better and may be

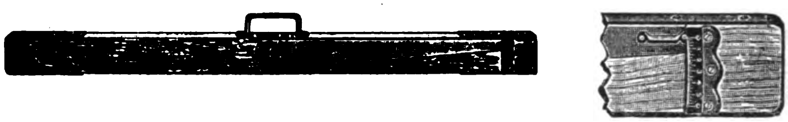


Fig. 311.—Duplex Track Level.

used if a track level is not at hand. Level boards should not be ironed off or shod with metal wear plates. Such construction increases the weight and also the severity of whatever jarring to which the tool is subject. The metal protection (?) and the work of putting it on also cost more than the board, which will wear many years without it, and when worn out it is, after all, nothing but a piece of board to be thrown away. Slight wear of the edge amounts to nothing, or at any rate nothing more than the amount of the wear. As the proper elevation of a curve cannot be determined with mathematical precision, and since in ballasting or tamping track some allowance must always be made for the track to settle, it is folly to split hairs on so many points respecting a track level. Too great care or attention cannot be given the spirit tube, however, since a slight error in setting it is multiplied many times at the end of the level board.

Level boards should be frequently tested, before using, the performance consisting simply in reversing the board on the same supports and noting the position of the bubble, as above explained. It should then be required that when the bubble fails to center on level supports by a certain amount the board should be sent to the shop for repairs. A writer in the "Roadmaster and Foreman" at one time described a level board with an adjustable guard plate used in the following manner: The guard plate is held to the board by bead-head screws through slots near the ends of the plate. In adjusting the plate to the proper position the board is either placed on two supports known to be level, in which case the center mark on the plate is moved to position over the middle of the bubble, or the board is reversed on supports nearly level and the center mark brought to a position midway between the two positions of the bubble for the reversal.

128. Track Jacks.—Not a few are opposed to the use of the track jack, but it is nevertheless a money-saving device on any section, especially if the crew or force is small. With the aid of a jack a crew as small as two men can raise and tamp track to advantage, because the jack can be set to hold the rail while both tamp, whereas, did they use a bar or lever for raising the rail one man must necessarily hold it down ("roost on the bar," as one roadmaster has expressed it) while the other blocks or tamps the tie, unaided. And more than this, the jack has to be set only once, but in a considerable lift with a raising bar the fulcrum may have to be adjusted two or three times before the track is lifted to the desired hight. A man can also raise a heavier load with a jack, because the leverage is greater than it can readily be made with a bar and fulcrum.

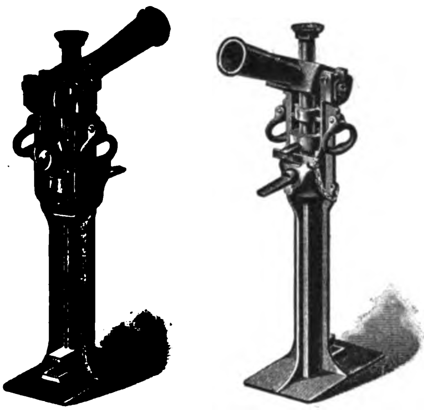


Fig. 312.—Jenne Track Jack.

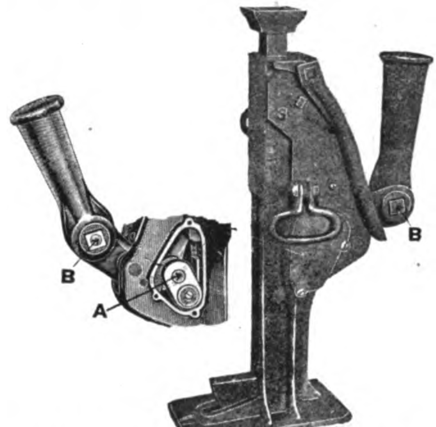


Fig. 313.—Q & C Compound-Lever Jack.

There are track jacks of many patterns. In the most general form there is an upright frame carrying a lifting bar provided with a projecting foot or claw to engage with the rail, the lifting bar being operated by a lever. In an old form the rail is raised by the direct action of a screw turned in an upright frame by a double-handed crank. The screw operates a malleable lifting nut which slides up and down in the frame and engages the rail. In jacks of the common form the lifting bar is operated either on the principle of the ratchet or the friction clutch. One of the best known jacks is the Jenne, shown in Fig. 312. The lifting bar is encircled by two stout rings bored at an angle and $^1/_{32}$ to $^1/_{16}$ in. larger than the diameter of the bar, so that when held in a horizontal position they clutch the bar. The upper ring engages with a hanger or link attached to the lever, and is known as the lifting ring. The lower ring is known as the retaining ring, and rests by a tail piece which projects through a hole in the frame. The support of both rings is by a tail piece or spur, so that a leverage is had on the bar to facilitate the clutching action of the ring. The load is dropped instantly by placing the cross pin under the tail piece of the lifting ring, bearing down on the lever to release the lifting bar from the grip of the retaining ring, and then pressing the tail piece of the retaining ring with the foot; bearing down still farther on the lever, the tail piece of the lifting ring meets with the cross pin and trips the lifting bar. Some trackmen do not use the cross pin at all, but trip the jack simply by removing the lever from its socket and with it jabbing the tail piece of the retaining ring. If the track has not far to drop this can be done, but otherwise the lifting bar will be caught and held by the upper ring. The load can be lowered slowly or by a small amount by bearing down on the lever until the lifting ring holds the load, and then holding the retaining ring with the foot until the load has been lowered the desired distance. If the load is to be lowered some considerable distance, the lifting ring must be held by the tail piece while the lever is pressed down, so as to get a new grip higher up on the lifting bar. The frame and lever socket of this jack are made of malleable iron and the lifting bar and rings of wrought iron. It seldom or never gets out of order and, being readily taken apart, is easily repaired when broken or worn. The jack is made in sizes, ranging from a jack standing 35 ins. high (bar down), with a 15-in. lift, capacity 10 tons and weight 90 lbs., for heavy lifting in ballasting new track, down to a jack 27 ins. high with 10-in. lift and weighing 40 lbs., for light section work, such as raising low joints, etc. No oil or other lubricant should be used on this jack, for the rustier it gets the better it works. Oil and grease may be removed from the bar and rings by scouring them with sand or cinders or better by burning. The bar will not hold when it is frosty, but the frost may be quickly melted with lighted paper. When the lifting bar wears smooth and bright some hack it with a cold chisel to make it hold, but it is better to take it out and burn it.

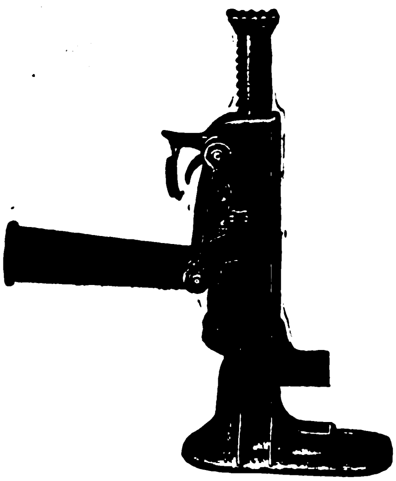


Fig. 314.—Boyer & Radford Jack.

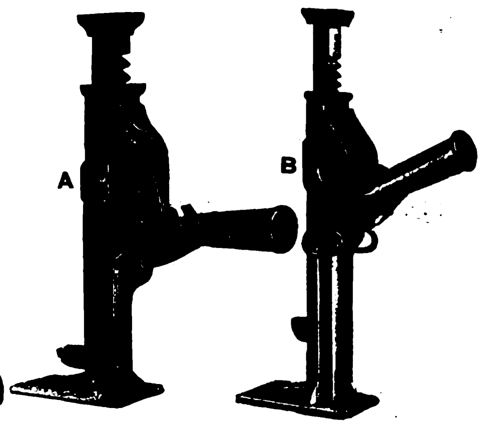


Fig. 315.—Barrett "Trip" Jacks.

The Hawkins jack operates also on the clutch or grip principle, the lifting bar being of circular section, as in the Jenne jack. In principle the operation is very similar to that of the Jenne jack, and about the only essential difference in construction is in the clutching mechanism. In place of rings for the lifting and retaining clutches there is, in each instance, a pair of knuckles engaging opposite sides of the lifting bar. The Q. & C. friction jack (Fig. 322) is quite similar in principle of construction to the Jenne jack, but the arrangement for tripping is simpler. The smallest size has a capacity of 10 tons, lifts 6 ins., stands 17 ins. high with bar down and weighs 55 lbs. Friction clutch jacks possess the advantage that the load can be raised and held at any desired hight, whereas in ratchet jacks the hight lifted cannot be adjusted closer than the length between teeth on the lifting bar, for single-stroke jacks, and half this length for double-acting jacks.

In ratchet jacks there is usually a notched or toothed lifting bar operated by a lifting pawl hinged to the end of a lever, and secured in position by a holding pawl hinged to the frame. In double-acting jacks there are two pawls hinged to the lever, at either side of its fulcrum, alternating as lifting and holding pawls according as the lever is moved on the up or down stroke; hence by this arrangement the lifting bar is moved on both strokes of the lever. In some jacks the lever is compounded, so as to effect a gain in leverage. The Norton "sure drop" jack (Fig. 320) of 10 tons' capacity is 24 ins. high, lifts 15 ins. and weighs 60 lbs. The jack can be tripped without lifting the load. The Verona jack (Fig. 318), of 10 tons' capacity, weighs only 51 lbs. The hight of the jack is 21 ins. and the lift 14 ins. The holding pawl *D* is pivoted to the frame astraddle the rack or lifting bar *B*, and the lifting pawl *E* is hinged with the lever shank *C*. The lever consists of a piece of pipe fitting loosely over the stem of the shank, as shown by the dotted lines. The lifting bar is tripped by pulling back the lower or lifting pawl and bearing down on the lever. By this action the lower pawl is shoved up against the holding pawl, thereby disengaging it. The load can also be let down one tooth at a time. The jack is carried about by taking hold of the stub lever.

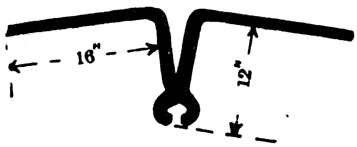
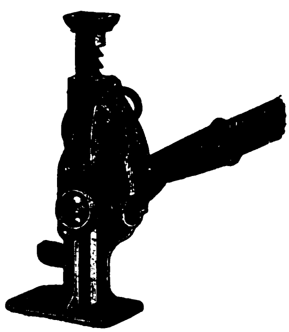


Fig. 316.—Rail Tongs.



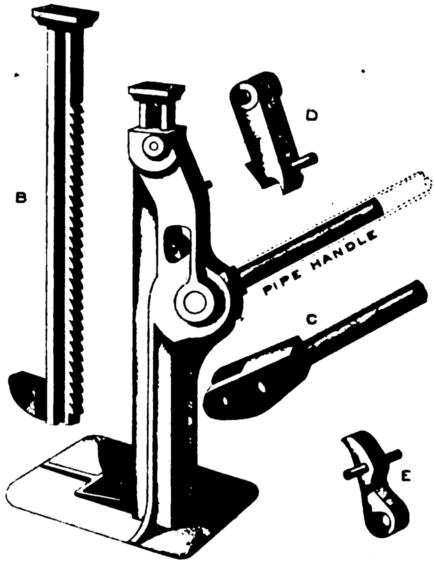


Fig. 317.—Barrett Automatic Lowering Jack. **Fig. 318.—Verona Track Jack.**

Among ratchet jacks the Barrett pattern is very well known and is made in a large variety of sizes and designs, ranging from a capacity of 10 tons, hight (bar down) 17¾ ins., lift 8 ins. and weight 50 lbs., to capacity 15 tons, hight 31 ins., lift 19 ins. and weight 110 lbs. Figure 315(*A*) is a view of "trip" jack No. 1. This jack stands 24 ins. high (with bar down), lifts 13½ ins., has a capacity of 10 tons and weighs 62 lbs. It is double acting, lifting the load on both upward and downward strokes of the lever, a half notch per full stroke. The load is tripped, from any elevation of the lifting bar, by a hook-shaped piece pivoted to the lever socket, which, when thrown forward, catches a pin projecting from the lower pawl and disengages both pawls, upon lowering the lever. View *B*, Fig. 315, shows a larger size of this jack, with a slightly different tripping arrangement, for heavy work in ballasting. The capacity is 15 tons, hight 31 ins., weight 105 lbs. and the lift 19 ins. To trip the lifting bar a small dog, pivoted to the lower pawl, is flipped forward, catching in a notch in the frame of the jack and disengaging both pawls, when the lever is actuated. This jack, and another of similar but lighter design, is also made single acting, elevating the load only on the downward stroke of the lever. The Barrett double-acting automatic lowering jack (Fig. 317) is designed to either raise or lower the load at both upward and downward strokes of the lever. The pawls are held to their work by coiled springs, and there is a thumb-screw at the side of the frame for reversing the order of engagement of the pawls, when it is desired to reverse the motion of the lifting bar. The jack shown is the smallest of four sizes, having a capacity of 10 tons, lift 10 ins., weight 63 lbs. and hight 21 ins. In a modified form of this automatic-lowering jack the lever is single acting, and in another form the double acting, automatic lowering and tripping features are all combined.

The Q. & C. compound-lever jack (Fig. 313), an improvement of the Moore jack, embraces still other features. The lever, instead of operating the lifting pawl direct, actuates two links forming a toggle joint or compound lever, and the lifting pawl is pivoted to this toggle joint, or at *A*, shown in the interior view. By this arrangement a powerful leverage is secured. The lever socket is jointed (at *B*) and is adjustable, as shown by the different angles at which it is set, thereby enabling the jack to be used in places where there is not room for a straight lever. The lifting bar travels one notch per half stroke or two notches per full

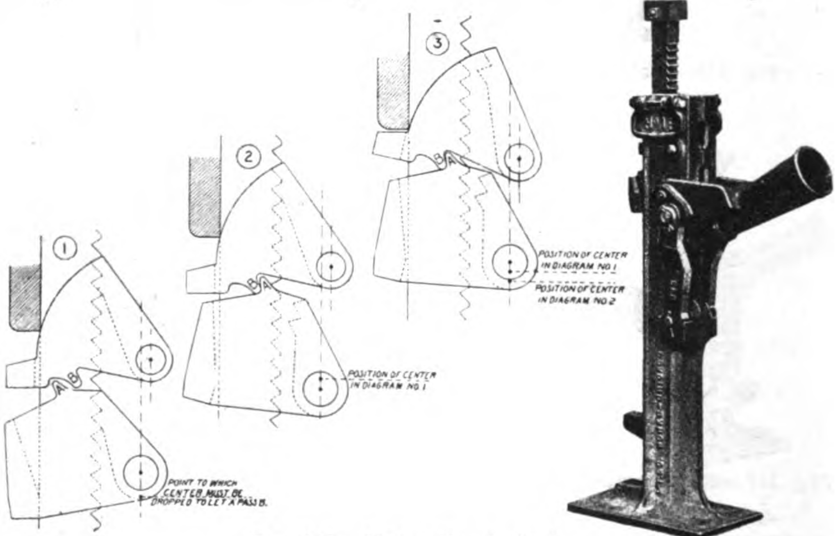


Fig. 319.—Union Track Jack.

stroke of the lever, which is single acting, and is tripped by a small lever or handle on the left side of the jack, as shown. There are three designs of this jack, one being provided with the tripping attachment, another with an automatic lowering arrangement, while the third design combines both these features—namely, tripping and automatic lowering devices. Each design is made in six sizes, ranging as follows: Hight, 18 to 32 ins., lift, 8 to 21 ins.; weight, 45 to 115 lbs.; capacity, 10 to 15 tons.

In the Boyer & Radford jack (Fig. 314) the lifting bar is reinforced the full length by a $\frac{3}{4}$-in. wrought iron bolt, to which the head is screwed. In other respects, also, this jack has some special features. The lever socket is pivoted to a pair of links hanging from the frame of the jack and the lifting pawl has seven teeth which fit into the ratchet of the lifting bar, thereby affording a very secure hold. The holding pawl also engages the lifting bar by teeth. The lifting bar has $^7/_{16}$-in. teeth, and it is raised or lowered two notches per full stroke of the lever. The jack is tripped by means of a floating hook attached to the upper pawl, which can be pushed down and in and fastened so as to hold the pawl out of position: upon raising the lever slightly the lower pawl is released and the bar drops. The lifting pawl is provided with projecting pins at top and bottom, which work loosely in slots in the sides of the frame, thereby limiting the movement of the pawl. The jack shown in the figure weighs 50 lbs., lifts 11½ ins. and has a capacity of 10 tons.

The Union track jack (Fig. 319) is designed with plenty of open space around the lifting bar, so that sand and dirt will not collect inside to clog the movement of the parts. The teeth in the lifting bar are spaced ½ in. apart and a full stroke of the lever moves the lifting bar through a vertical hight of 1½ ins., or a distance corresponding to the length of three teeth. The lifting bar and pawls are of hardened steel, the latter engaging with the lifting bar by double teeth. The lever is supported on a pair of links, and the manner of support is such that a movable fulcrum is obtained, thereby admitting of a variable leverage on the toggle-joint principle. By this arrangement it is possible, with the lever well down, by means of a short stroke, lifting through a distance corresponding to the length of one tooth, to obtain very powerful leverage, since, as the lever reaches the lower position of the stroke, the three joints or points of support come very nearly in a straight line. The movable fulcrum also permits the pin carrying the lifting pawl to travel in a vertical line, so that there is neither rocking motion of the pawl in the teeth of the bar, to cause wear and friction and

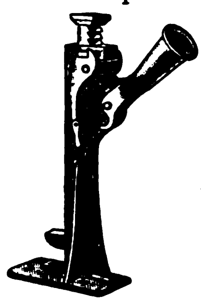


Fig. 320.—Norton Jack.

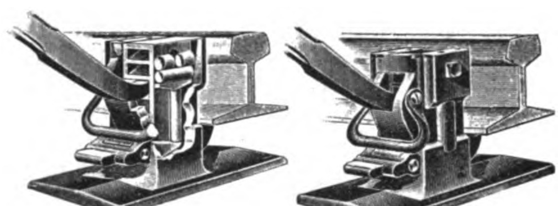
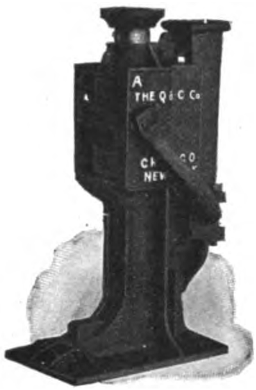


Fig. 321.—Anderson Track Jack.

consume part of the force exerted, in overcoming friction, nor is there a horizontal thrust tending to push the bar against the frame of the jack which, did it occur, would consume a considerable part of the force applied, in overcoming friction. The jack is tripped by the engagement of the lower or lifting pawl with the upper or holding pawl, and a depression of the lever, so that the lower pawl pushes the upper pawl out of its engagement with the lifting bar. Diagram 1 shows the position of the pawls when the bar has been raised to the full extent of a single stroke of the lever, and is at the point where both pawls are in engagement with the teeth of the lifting bar It will be noticed that there are two hooks or lugs, *A* and *B*, on the lifting and holding pawls, respectively. When it is desired to set the pawls to trip, the wooden handle is removed from the lever socket, the lever socket is raised so as to depress the lower pawl, and the lower pawl is swung outward, so that *A* passes *B*. The socket is then depressed until *A* passes upward into position back of *B*, as in Diagram 2. In this position the lower pawl is securely held out of engagement with the teeth of the lifting bar by the lug *B*, the upper pawl still sustaining the load. By pressing the lever socket farther down the lower pawl moves upward, throwing the upper pawl out of engagement, and the lifting bar is released and drops the load. In this position (Diagram 3) both pawls are held securely away from the teeth of the lifting bar, so that it descends without obstruction or hindrance. The first upward stroke of the lever releases both pawls and they engage the bar without further attention. With this jack it is possible to set the pawls for tripping as soon as the track has been raised to the proper hight, and it will remain in such position without dropping its load, while tamping or other work is being done. In case of emergency, therefore, the jack can be tripped instantly and removed without stopping to adjust any of the parts which have to do with the tripping action.

As a jack, at best, is quite heavy, it should be made as light as is com-



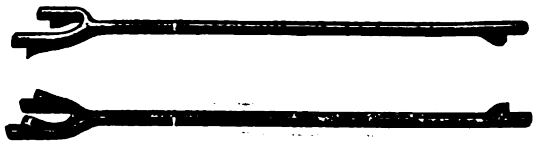


Fig. 323.—Sheffield Pressed Steel Insulated Gage.

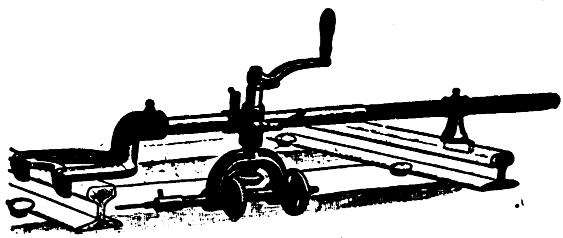


Fig. 322.—Q & C Friction Jack. Fig. 324.—Rail Bonding Drill.

mensurable with the strength required for the work. For general track repairs the weight should not exceed 55 lbs. For use in ballasting new track, jacks weighing 80 to 100 lbs. are commonly employed. A very important point in the design of a track jack is that is shall drop its load easily and without fail upon every attempt to trip the lifting bar. A jack of ordinary hight set between the rails forms an ugly and dangerous obstruction for a train to run against, as the cowcatcher is almost sure to fling it across the rail. A disastrous wreck caused by a track jack on the Old Colony R. R. in 1890 (the particulars of which are related in § 113, Chap. VIII) had for some years the effect of bringing this tool into disrepute with railway officials, and on practically all roads the rules forbid the use of a jack between the rails. When used outside the rail and between the ties it interferes with the tamping of one side of the tie, to hold the rail to place at the point raised, and in most cases the plan of lifting against the bottom of a tie involves so much digging that it is impracticable. It must be admitted, however, that on curves and at points where the view is obstructed the use of a jack between the rails is attended with considerable danger to trains, for no matter how "sure drop" the jack may be, the unexpected arrival of a train will throw some men into confusion; or at any rate queer movements have been known to take place on occasions of this kind. Such considerations make it desirable that for old track a jack may be had which can be used between the rails and still stand so low as to be clear of trains which might pass over it unexpectedly while set in the track. Some short-lift jacks of this description have been devised and put to use. One of these is the Anderson friction jack, which has been used on the Chicago Great Western, New York, New Haven & Hartford and some other roads. This jack stands only 8 ins. high and, as appears in Fig. 321, does not project above the top of rail. It therefore presents no danger of derailment if a train passes over the jack in service. The lifting bar of the jack is raised by a ratchet arrangement and held by a friction clutch, thereby enabling the device to raise and hold the rail, or lower it, to any fraction of an inch. The range of movement of the lifting bar is 5 ins. As shown in the figure, the back of the lifting bar is notched and is operated by an ordinary pinch bar. At each side of the lifting bar there is a wedge-shaped pocket in which are placed three roller gravity pawls, the upper two being separated by a bolt passing entirely through the jack, the lifting bar being slotted. The jack is released by a foot trip, which appears directly under the handle. This trip consists of a lever which throws up a stem against the under side of the pawls, thereby disengaging them and allowing the lifting bar to drop. The body or frame of the jack is cast in one piece and the entire weight of the tool is but 33 lbs. The pawls can be taken from each pocket by removing two screws and lifting the top plate. The Fisher jack is made to work under the rail base, requiring that considerable digging must be done, in order to set it, thereby seriously delaying the work; it also forms as much of a hindrance to tamping the tie next it as does a jack of ordinary hight set outside the rail. It consists essentially of a toggle joint carrying a bearing plate at the apex to engage the rail. The two legs of the toggle are worked by a ratchet lever and screw, the latter passing horizontally through nuts at the feet of the toggle legs, the thread on the two ends of the screw being right and left-handed.

It is important that a track jack should have a base of good size, so that it will not settle deeply into the ballast when lifting the track, or tilt over and throw the track out of line. The size of base recommended by the Roadmasters' Association of America is 7x12 ins. To prevent the jack from tipping, the base projects farther in front of the upright frame than behind it. In using the jack trackmen should get in the habit of planting it squarely or setting it perpendicular to the plane of the track, so as to disturb the alignment of the track as little as possible. Tools with parts subject to wear, like jacks, rail drills, rail-sawing machines, hand cars, etc., should be bought under a guarantee that interchangeable parts will be supplied if desired.

129. Raising Bars.—Although a jack is the best raising tool for general purposes, every section ought to be provided with a long, stout bar. It comes into use occasionally and is a good tool to fall back upon in case the jack gets broken or is sent for repairs. A wooden lever shod with iron at the tip (Fig. 32) is out of date in section work. Being heavy and unwieldy, too many men are required to carry it around and operate it, and in a lift of any consequence it is bound to throw the track out of line, more or less. When such tools were commonly used a rope was sometimes tied to the end of the lever to pull it down when setting it for a high lift. On old track which has been well kept up, and where the bed is hardened, so that most low places do not require raising more than an inch, good work can be done with a raising bar, providing the operator knows how to use it. If, however, the track is on a new bed, and places settle 1½ ins. or more before they are raised, the jack is the better tool. The bar should, of course, be a pinch bar, with the point turned up slightly more than on ordinary pinch bars, so as to give more of a heel. It should be about 6 ft. 3 ins. long and weigh about 40 lbs. The large end of it should be about 1¾ ins. square for about 2 ft. and then taper off gradually, first to octagonal section and finally to 1⅛ ins. round, at the end. The man operating a raising bar carries with it a block of hard wood, about 2x6x15 ins. in size, with one end beveled. This block is shoved under the rail base, so that the bar rests upon it at about the middle. By raising once on the block, if it be not set too far below the rail base, and then using a nut or hard stone about an inch thick, for a fulcrum, track can be thrown up 1 or 1½ ins. pretty lively and satisfactorily.

130. Rail Tongs.—Rail tongs should be about 12 ins. long, from the jaw to the bend in the reins or handle (Fig. 316). All the tongs on the same division should be of the same length, so that in case they get mixed

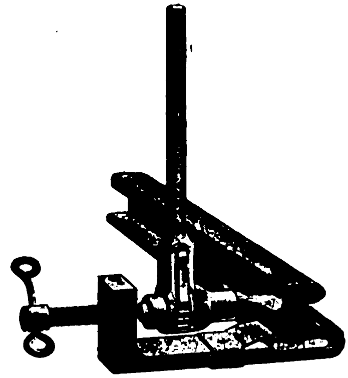
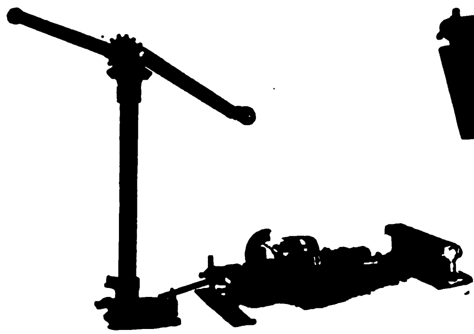


Fig. 325.—Doyle & Williamson Drill.



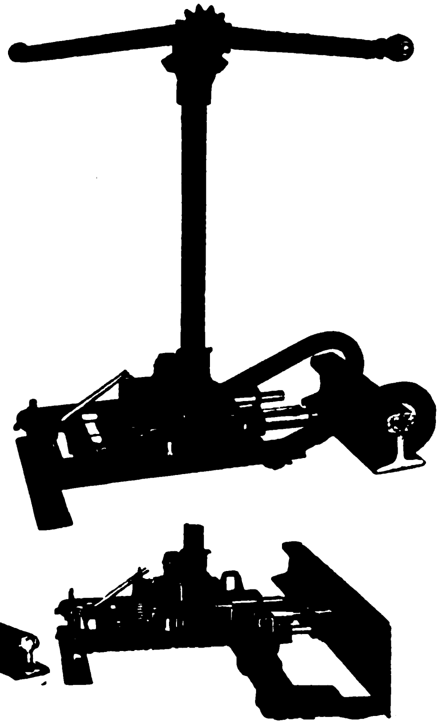


Fig. 327.—Drill Taken Down for Train. Fig. 326.—Q & C Track Drills.

up one crew will not get hold of different lengths. The reins should each be about 16 ins. long, or 32 ins. long over all. The tool is made from two pieces of 1-in. round iron, each 26 ins. long, to which the jaws are welded. The jaws should be about 1½x¾ in. at the pivot, which is held by a ½-in. rivet. The weight of such a pair of tongs is about 11½ lbs. Tongs of heavier construction, as shown in Engraving *F*, Fig. 295, weigh about 15 lbs. Soft steel is good material for tongs. Tongs are very useful when laying turnouts, where many rails have to be handled, but especially if the weather is very hot and bright, making the rails exceedingly uncomfortable to handle with the bare hands. Four men with two pairs of tongs can handle rails more easily than six men bare-handed. In case six men with three pairs of tongs are given a rail to carry, the men with the third pair of tongs should not carry at the middle of the rail, because in going over uneven ground the rail will be either too high or too low for their reach and put them to a disadvantage. In order to distribute the weight equally among all six men and enable them to carry the rail over uneven ground without disadvantage to any one, one pair should carry at one end and the other two pairs, as near together as they can walk conveniently, at ¼ the length of the rail from the other end. The same manner of distribution applies when three men carry a tie; one man at the rear end, the other two carrying with a stick at ¼ the tie length from the front end. The question of properly distributing the weight of a tie on three men, when two of the three carry with a stick, is frequently debated among trackmen.

131. Rail Drills.—The simplest device for drilling rails is the ratchet drill. The simplest form of ratchet drill consists of a stock or bit holder, operated by a ratchet wheel, hand lever and pawl. Some kind of a clamp must be provided as a backing for the stock, and the bit is fed by a screw working into the stock and against the clamp. Drill clamps are made to engage the rail in two ways—the "underclutch," fitting under the base of rail, and the "overclutch," fitting over the rail head. The underclutch arrangement has the advantage that the clamp need not be removed for the passage of a train, and the disadvantage that spikes must sometimes be pulled and the rail raised in order to place the clamp properly (over a tie, for instance) for drilling through a rail in place in the track. The overclutch arrangement can be applied to a rail at any point, without preparation, but the clamp must be removed to let trains pass. In yards and at other points where the ties are covered up an overclutch fastening for a drill is very convenient, and sometimes saves a great deal of digging. An underclutch clamp may consist simply in a stout bar of iron or steel of proper length bent up at both ends. In the Doyle & Williamson drill (Fig. 325) the clamp has a sliding collar and clasp, as a means of securing the clamp to the rail flange, and the feeding screw works through one leg of the clamp and against the bit stock. A more convenient underclutching arrangement is formed by two clamps placed 15 to 18 ins. apart and joined by a back piece parallel with the rail, thus forming a frame along which the drill may slide, so that several holes may be drilled at one setting of the clamp. In this form of clamp the range of adjustment for the drill is such that it seldom becomes necessary to clamp the frame to the rail over a tie, which requires, as above noted, the spikes to be pulled and the rail raised. The frame is sometimes made solid, in one piece, as in Fig. 329, and sometimes the back piece (B) is held at an adjustable distance from the rail by pins

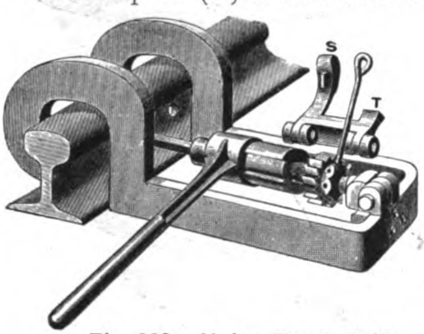


Fig. 328.—Union Track Drill.

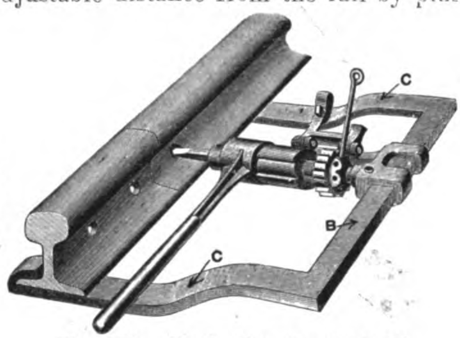


Fig. 329.—Perfection Track Drill.

in the slotted ends of the two clamping pieces (C), as shown in Fig. 330. In the clamping frame for the Beland drill the back piece is formed by two flat bars, with the shank of the drill sliding between them. The back piece is sometimes provided with a projection of some kind on the under side, to hold the frame up and keep the drill clear of the ties.

One of the oldest track drills is the Victor (Fig. 332), designed by Mr. J. H. Lakey, master mechanic with the Chicago & Northwestern Ry. It works with a clamp of the overclutch kind, fastening to the head of the rail by a cast iron wedge W, which is driven in between the rail and a depending lug on the clamp. The drill may be unclamped from the rail in an instant by knocking out the wedge. The feeding screw acts directly on the bit, which has a square shank. With this form of clamp it is possible to drill a short, loose piece of rail without having to spike it to a tie or otherwise make it fast against overturning as the bit is worked. With most forms of clamp this cannot be done. The principal trouble with this drill is that the clamp can be made for a rail of only one size and shape, and as the rail head wears down it becomes more and more difficult to hold the clamp to the rail securely. The Union drill (Fig. 328) has a clamp or frame which hooks over the rail head and bears against the web on the opposite side, fitting rails of any section. The ratchet is encased and the bit is fed either automatically or by hand, as desired. In order to remove the clamp from the rail quickly a pry is taken under the feed drum or feed ratchet with a bar, pick, wrench or other convenient lever, throwing the drill out of center. In this drill, as with the Perfection drill (Fig. 329), the automatic feeding arrangement consists in a slotted drum and a finger (S) bearing thereon by a nub, the finger being joined to a pawl (T), as shown. Once in every turn the slot permits the finger to drop, thereby throwing the pawl into engagement with the feeding ratchet while the nub on the finger is down in the slot.

A drill possessing several novel features is the Warren, shown in Fig. 333. The bit stock and feed work through a block with two ratchet sides (R), and this block is adjustable on the ratchet seat (S) of the clamping frame, and is held in the same by a pin. The feed screw is of sufficient length to drill four holes through the rail web without backing the screw, so that in resetting the drill for the last three of the four holes it is only necessary to move the block farther back on the ratchet seat. As the bit

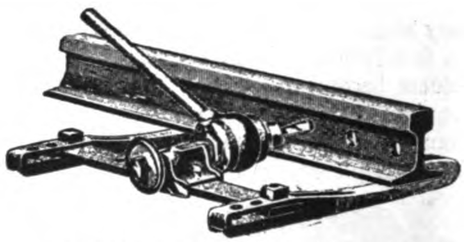


Fig. 330.—Schuttler Track Drill.

Fig. 331.—Paulus Track Drill.

stock is not centered in the block, the drill is adjustable to two hights of rail by reversing the block. A shankless twist bit is used and it is forced into the rail by a friction feed which can be regulated (increased or decreased) by means of a thumb-screw. The same drill is worked with an underclutching clamp, the only change required being a ratchet seat attached to that form of clamp.

In the drills thus far considered the lever has been single acting—that is, the bit stock is turned by the lever only one way of the stroke. In the Schuttler drill (Fig. 330) the bit is turned continuously forward at both forward and back strokes of the lever, thus dispensing with all idle movement in the lever. The continuous action of the drill spindle upon the reversal of the lever is obtained by means of a pair of gears between which is meshed a pair of beveled pinions. One of the gears is rigidly attached to the spindle and the other is loose, and in the outer circumference of each gear are ratchet teeth set to do service in opposite directions. There are two pawls. When the lever is moved in one direction a pawl engages the fixed gear and the action on the spindle is direct. When the lever is reversed, a pawl engages the loose gear, and, by means of the intermediate bevel pinions, the fixed gear is turned in the same direction as before, so that the spindle is driven always forward. To keep dust out of the turning mechanism the gears and pinions are enclosed by a case in two pieces held together by hexagonal nuts.

Continuous-motion drills operated by hand cranks do the work most rapidly, and are extensively in use, particularly with yard gangs or wherever a good deal of switch work is to be done. In these machines there is usually an upright shaft with two cranks and bevel gear connection at the top, and a horizontal bit stock and bevel gear connection at the bottom; some means for clamping to the rail, and provision for quickly removing the drill from the reach of passing trains. The Waterman, Buda and Paulus drills are all very similar in respect to these particulars. Figure 331 shows the Paulus drill in position for work and also thrown back to allow a train to pass. More in detail, the apparatus consists of a firmly stayed upright frame supporting a shaft, to which are attached two handles, enabling the machine to be worked in continuous motion by either one or two men. At the back of the horizontal portion of the frame there is a sole plate serving as a support for this part of the machine and for the automatic screw feed mechanism. Attached to the horizontal portion of the frame there are two rail hooks, which hold the drill to its work. The motion of the handles is transmitted to the stock spindle by bevel gears on a vertical

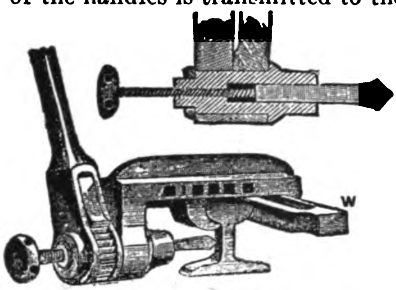


Fig. 332.—Victor Track Drill.

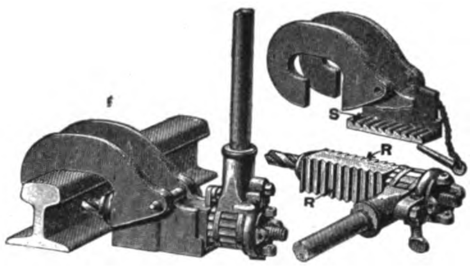


Fig. 333.—Warren Track Drill.

shaft. A simple ratchet device, actuated by an eccentric, feeds the drill automatically. The upright is held firmly in place by a back brace, formed by rule-jointed stay rods joined by a wooden handle. When it is desired to unclamp the machine the back brace is folded by pulling out the wooden handle, the operation requiring but a few seconds. The rail hooks are pivoted to L-like extensions of the upright frame, so that when the latter is tilted backwards the hooks are swung forward far enough to clear the rail head. As the upright frame is being tilted backward the bevel gear which transmits the turning motion from the vertical shaft disengages from its companion on the horizontal spindle holding the bit. With this machine a $\frac{7}{8}$-in. hole can be drilled through the web of an 80-lb. rail in about two minutes The weight of the machine is 60 lbs., but for very heavy work a drill is made of the same pattern weighing 90 lbs. For special work the drill is made with a hook to fit under the base of the rail instead of over the head of it, as shown in the figure. In the Q & C self-feeding rail drill (Fig. 326) the upright shaft is detachable from the horizontal portion of the mechanism and can be quickly lifted out of the way of passing trains. By folding back the hooks all remaining parts of the drill are out of reach, as shown in Fig. 327. It is made with either underclutch or overclutch fastenings (Fig. 326), the drilling mechanism proper being substantially the same in either case. The main frame slides forward on guides carrying the drill spindle with it and a small lever at the back clamps the hooks to the rail, or releases them when thrown back.

In bonding rails for track circuit, in signal or electric railway work, the holes drilled usually run from ¼ to ½ in. in diameter. For such light work a drill is required which is easily portable, rapid in action and light in weight. One of the best known devices for this work is shown in Fig. 324. The drill stock is turned by crank and bevel gear and the bit is fed by a screw and hand wheel. The drill in this machine is adjustably clamped to a piece of 1¼ or 1½-in. pipe laid across the rails. One end of the piece of pipe is screwed into a fork with lugs to catch over the rail and hold the drill up to its work, and the other end may lie across the rail or on a supporting block, as shown. The bit can be set at any desired hight by turning the drill about the pipe and clamping it at the proper point. The man who operates the drill either sits on the pipe while he turns the crank, or holds it down by foot pressure. The weight is 68 lbs. A drill of similar pattern for heavier work is shown as Engraving *S,* Fig. 309. The machine has two extension cranks, facilitating the application of a greater turning force on the bit, when necessary, and there is an automatic friction feed which can be adjusted for fast or slow feeding. Arranged as shown in the illustration, the speed of crank and spindle are geared as 1 to 1, but by removing the top yoke and placing one of the cranks on the upright shaft the gearing is changed to give two revolutions of the spindle to one of the crank. This latter arrangement is adapted for light work and rapid drilling, as when drilling holes for bond wires. The machine weighs 85 lbs.

IN POSITION FOR WORK.

THROWN BACK TO DETACH FROM RAIL.

Fig. 334.—Wilson Drill for Rail Bonding.

The Wilson machine (Fig. 334) is designed specially for light drilling, its weight being only 20 lbs. The machine is clamped to the rail by overhanging hooks and a lever and link motion, which moves the upright part of the drill forward to its work, when the lever is thrown up, and withdraws it when the lever is thrown down. In the latter position the frame slides back far enough to clear the drill point from the head of the rail, so that the machine is entirely free and can be taken direct from the rail. The driving gear consists of sprocket wheel and chain. On the crank shaft are two sprocket wheels: one, fastened rigidly to the shaft and revolving with it, drives the feed nut on the drill spindle; the other is placed loosely on the shaft and does not revolve unless engaged by a pawl on the end of the shaft; when so engaged it drives the drill spindle. Thus the drill spindle and the feed nut both revolve in the same direction, but are so geared that the feed nut travels a little faster than the drill spindle, and so imparts a continuous feed, either forward or back, as the crank is turned. By disengaging the pawl on the sprocket wheel which drives the drill spindle the latter may be held from turning while the feed nut is revolved, thus imparting a quick forward or back movement to the drill spindle which can be utilized to good advantage in setting the drill.

For drilling bolt holes 1-in. bits or larger are used. Twist bits usually give better satisfaction than flat bits. When bits get dull they may be sharpened on the grindstone. With twist bits this method of sharpening can be repeated indefinitely, but flat bits must be heated and worked over occasionally. Before starting a bit it is well to spot the place with a center punch. A desirable feature in a drill is to be able to adjust the bit to the required hight of the bolt hole, so that it will do accurate work on rails of more than one particular section. Unless this adjustment can be made it is sometimes necessary to block up the frame and drill the hole obliquely, in order to get it at the desired hight.

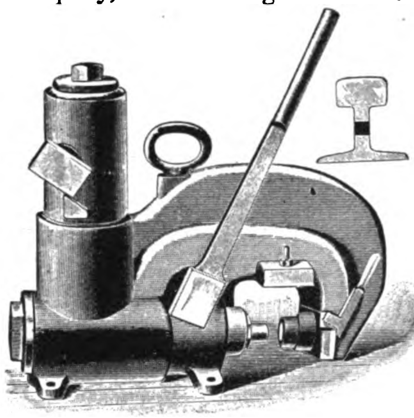


Fig. 335.—Hydraulic Rail Punch.

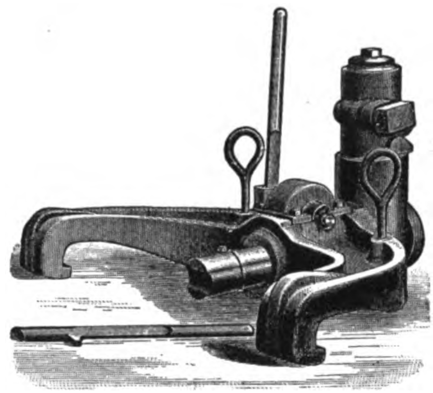


Fig. 336.—Hydraulic Rail Bender.

In the days of iron rails bolt holes were frequently made with hammer and punch, but this method has nearly disappeared from practice with steel rails. The method of procedure in punching a rail by hand is to notch in a square hole on one side of the web, as far as may be practicable with a cold chisel, and then turn the rail over and punch through with a round punch, driving the core toward the side on which the notching was done. The punching of bolt holes with hydraulic machinery is done to some extent. Figure 335 is a view of the Watson-Stillman hydraulic rail punch. It is portable and may be used on rails in place in the track. The lever shown in the middle of the view is for quick action, being used to work the ram in and out a distance of about 2 ins. without loss of time and labor of pumping. At the top of the jaw there is a guide which can be set to suit the pattern of rail handled, so that all holes punched will be at the same hight on the web of the rail. For punching rails weighing 70 lbs. per yard, or less, a machine of 50 tons' capacity, weighing 200 lbs., is used; for heavier rails there is a machine having a capacity of 120 tons, weighing 375 lbs. For punching slots in the rail flange, for spikes, there is a machine of similar construction in which the ram acts vertically.

132. Rail Benders.—The most common form of rail bender is the jim-crow, Fig. 337. It consists of a heavy U-shaped forging of iron or steel, the two legs of which have their ends hooked for holding against the head of the rail, while a screw working through the center or bend of the frame bends the rail midway between its bearings against the two hooks. The screw is usually made to do its work on the rail by exerting pressure against a cast iron block of proper shape, placed against the side of the rail. The screw usually has a capstan head and is turned by an ordinary pinch bar, but sometimes the head is made to be turned by a long wrench. For turning screws of this kind the Pennsylvania Steel Company supplies a large wrench with a ratchet head. Jim-crows for ordinary service are about 2 ft. wide, c. to c. of arms, have a screw $2\frac{1}{2}$ to 3 ins. in diameter and weigh 150 to 200 lbs. The "Eccentric" rail bender (Fig. 338) has two hooked legs forming an A-frame, with a pressure rod worked by a lever and eccentric. The pressure rod is made adjustable by a sleeve nut, so that the amount of bending or the leverage can be changed to suit the circumstances. The weight of the tool is about 180 lbs. The Emerson rail bender is very similar to or like the Eccentric design. With benders of this type it is sometimes necessary to use the lever several times, readjusting the sleeve nut each time, in order to bend the rail the desired amount. The Fairbanks-Morse bender, which works on the eccentric or cam principle, has self feeding wedges on the ram which automatically feed it forward at each stroke of the lever. The Samson rail bender (Engraving *B*, Fig. 339) is a heavy cast steel lever with a capstan-headed screw at one end and a stout claw near the other end. The screw works into a cast steel cap with phosphor bronze and tool steel bearings, this cap being grooved to fit against the rail head. The lever or frame has a broad web with heavy flanges, and the tool weighs 113 lbs.

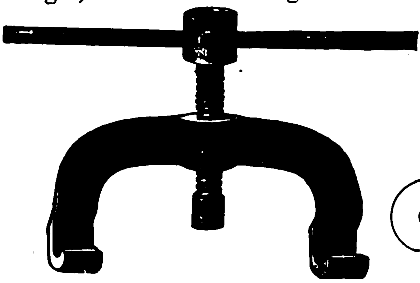


Fig. 337.—Jim-Crow Rail Bender

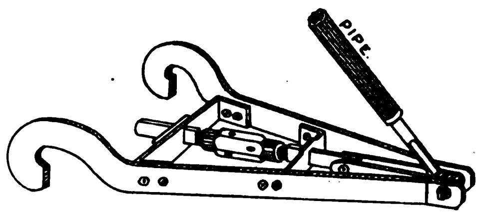


Fig. 338.—Eccentric Rail Bender.

Figure 336 shows the Watson-Stillman hydraulic rail bender, designed especially for work on heavy rails. It is made in two sizes: one weighing 200 lbs., for rails of 70 lbs. per yd., or lighter, and one weighing 275 lbs. for rails heavier than 70 lbs. per yd. The ram has a loose steel head which fits against the rail head and the ram is graduated to show the spring of the rail.

133. Hand Cars.—The term hand car signifies, of course, any car propelled by hand, and, in a general sense, it might as well be understood to include all cars propelled in any manner which are lifted on or off the track by hand. As commonly used, however, the term applies only to vehicles for carrying section or bridge crews with their tools (Fig. 340). Cars for this purpose differ but little in general features of construction. There is usually a platform carried on four wheels, on which is mounted an A-frame or gallows frame supporting a walking beam or lever with cross handles, attached by connecting rod and crank to spur gear wheels operating on the axle of the car. Cars for section crews are usually about the same size on all standard-gage roads and are made in about the same way. The platform is usually 6 to 6½ ft. long and 4 ft. 4 ins. or 4 ft. 5 ins. wide, formed upon four longitudinal sills about 2½x1½ ins. in section, the sills extending beyond the platform on both ends and rounded off for handles. The two outer sills rest on the journals or axle bearings and the two inner or middle sills carry the gallows frame. The longitudinal sills support cross pieces, on which is laid a floor of matched lumber. The axles are of steel and about 1½ ins. in diameter. Roller bearings are used to some extent. The lever has forked ends, each prong terminating in an eye band which holds the handle. Six men can usually "pump" without interference and two or three more men standing between the handles can help a little. A dozen men can easily stand on the car, and at a pinch the car will carry

18 or 20 men. Years ago hand cars were sometimes made large enough to carry easily a crew of 25 or 30 men, the car being propelled by means of two long wooden levers. Such cars, however, were heavy to handle and, notwithstanding the large crews carried, were lifted to or from the track with some difficulty. The smaller cars in common use with section crews are to be preferred for large crews also, two or more cars being furnished as the size of the crew may require. Hand cars propelled by two cranks were formerly used to some extent, but have largely gone out of service. Such cars give opportunity for only two men to work at propulsion, and the motion of the cranks, unless carefully and continually watched, is somewhat dangerous to men standing on the car. On account of the larger and heavier tools carried a hand car for a bridge gang is made heavier than the section hand car. The platform is usually about 8 ft. long and 5 ft. 6 or 8 ins. wide, extending over the wheels. In order to obtain a desired width of platform on hand cars for narrow-gage track, the platform is extended over the wheels. An important feature of design in all hand cars is to get the wheels far enough apart to obviate the danger of upsetting the car when the two ends are unequally loaded to the extent of a man or two.

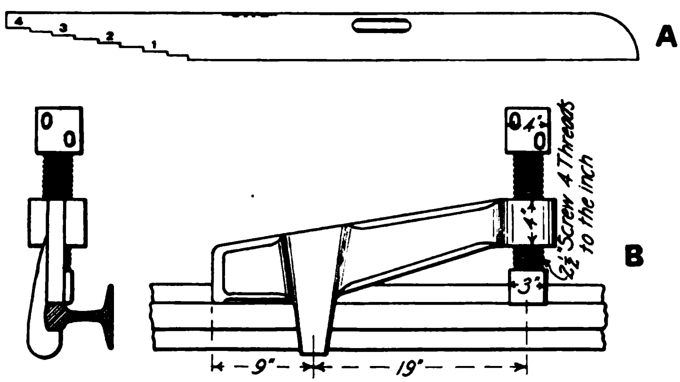


Fig. 339.

The most important considerations in a hand car are the weight and the speed, or the distance the car travels for a stroke of the lever. A feature which has to do largely with the weight is the manner of construction of the wheels. The old form of wheel, where the tire and hub were cast-welded around wrought spokes, is too heavy and is not so good a wheel as some of the lighter forms now made. One difficulty with this old form of wheel was that an extraordinary load on the car would loosen the spokes, after which the wheels would wabble in running. Wheels of pressed steel or wheels made with wooden rim and spokes, or steel plate center, with steel tire, are best for hand cars, as such construction can be made sufficiently strong and save much weight over the older forms of cast or cast-welded wheels. On roads using automatic electrical block signals with track circuit the hand car wheels must have wooden centers or insulated axles. The web of pressed steel wheels is usually dished and ribbed or corrugated radially, so as to effect a gain in stiffness. In the Buda steel wheel (*B*, Fig. 309), made from a single plate, the tread is doubled back upon itself half its width, so that the wheel center is in line with the middle of the tread, or in the direct line through which the weight on the wheel bears. The metal is shaped by drawing and spinning, without seam or weld, and the wheel complete weighs 40 lbs. The Kalamazoo wheel has a steel plate center and a pressed steel tire or tread. The "Cyrus Roberts" hand car wheel has a hub cast-welded around steel spokes which are screwed firmly into the felloe.

A steel flanged tire is then shrunk over the felloe. The style of wheel in most extensive use is a dished steel plate with portions of the metal cut away or bent back, leaving the spokes. A section of the Sheffield pressed steel wheel is shown as *F*, Fig. 309. The Donovan hand car wheel (Engraving *E*, Fig. 309), like several others, is pressed from one piece of steel plate. The engraving shows views of both the outside and inside of the wheel. The metal struck out between the spokes is turned inward at right angles to support the tread. The hub plate is cast-welded on both sides of the web and through the spaces between the spokes, forming a single casting which closely binds the parts together without bolt or rivet.

The frame of a hand car can be much lightened by a proper disposition of brace rods. Both longitudinal and cross sills should be trussed and the platform should be braced diagonally to keep the wheels in tram or in position to track properly. The gallows frame, if of wood construction, should be braced diagonally, to keep it from getting rickety. Section hand cars sufficiently strong to carry as many men as can conveniently get on them, with their tools, need not weigh more than 500 lbs. A heavy car is

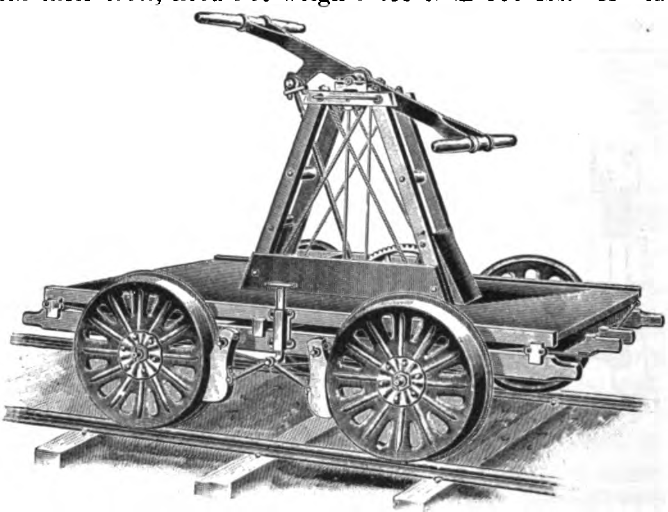


Fig. 340.—Sheffield Section Hand Car.

unwieldy to get on or off the track, is more liable to be damaged in being moved to or from the track, and runs hard; which means that it cannot be propelled as fast as a lighter car well constructed. The car illustrated as Fig. 340 weighs 480 to 545 lbs, according to the thickness of metal in the wheels, but the car of this pattern weighing 510 lbs. is considered heavy enough and strong enough for all ordinary purposes. All parts of a hand car should be made as light as possible for the strength required, and manufacturers, who, as a rule, have studied the matter closely, and experimented a good deal with the materials required, have the business down to its finest points. As a general proposition better and cheaper hand cars can be had from them than are turned out from railway shops.

The two features of hand car design which determine speed, for a given outlay of strength, are the sweep of the handles and the distance the car travels per stroke of the lever. In a mechanical sense a hand car is propelled by prime movers working in parallel. The physical exertion of pumping the car may be analyzed into two processes—the expenditure of "elbow grease" and the movement of the body in bending the back. As a matter of efficiency, therefore, a large part of the energy generated is lost in the prime mover. It is for this reason that the sweep of the handles and the travel of the car per stroke of the lever are all-important considerations; because the former has to do with the extent of, and the latter with the rapidity of, the back-bending action. The lever handles should have a sweep up and down of about 24 ins. and the sweep of both ends of the lever should be the same, or equal, and between the same limiting distances from the car floor. In order that this condition may obtain, the lever or walking beam must be equally divided across its axis or supporting shaft and the connecting rod must be of a certain fixed length. A sweep of the handles exceeding 24 ins. requires rather too much motion or bending of the back. Since large wheels are run at a given speed easier than small ones, the wheels of a hand car should be not less than 20 ins. in diameter. These two requirements—the sweep of the lever handles and the diameter of the wheels—being fixed, and a gear ratio to produce a given speed being determined upon, it matters not how the driving gear is otherwise arranged. The length of the crank and the leverage of the handles are dependent upon each other; the longer the crank of the speed wheel or driver, the less can be the leverage or purchase given to the handles, the length of the lever to which the handles are attached being unimportant so long as the sweep of the handles remains fixed. So it matters not whether the crank be longer and the leverage less, or the crank shorter and the leverage greater. The ratio between the number of gear teeth on the driver and pinion depends upon the required number of revolutions of the wheels in order to travel the given distance per stroke of the lever; and it matters not whether these two gear wheels be larger or smaller, so long as the number of teeth on each bear the same ratio to each other.

In general, two speeds for hand cars are required: viz., one speed for grades and another for the level. A car operated up grade will necessarily run slower for a given outlay of strength than when operated on the level. As the speed up grade must then be comparatively slow, necessarily, and as to accomplish the same work in propelling the car less force or pressure on the handles is required at a quick stroke than at a slower one, the car best suited for grades favors the quick stroke. On the level the opposite obtains; that is, the car best suited for the level favors the slow stroke, because at a high speed of the lever men can put less force on it, and much work developed in rapidly bending the back is lost, as far as the work done upon the car is concerned. For sections having heavy grades—say over 1½ per cent—hand cars ought to be speeded to run not over 15 ft. per full stroke of the lever (up and down), and an arrangement should be provided by which the pinion may be slipped and the drive wheel thrown out of gear while running down grade. For ordinary grades 17 ft. run per stroke is about right. For the level or slight grades, 22 to 25 ft. run per stroke of the lever enables men to run a car at good speed with a minimum rate of work developed in the back and arms. The Roberts Car & Wheel Co. makes a special double gear, with slip pinions, for hand cars. The crank shaft carries two speed wheels of different diameters, and the driver axle, which is of square cross section at the middle, carries two slip pinions, worked by horizontal levers extending under the platform to the end of the car. The larger pinion matches with the smaller speed wheel, forming the "slow gear," for grades, and the small pinion and larger speed wheel provide the "fast gear," for level track. To stop the motion of the lever when coasting down heavy grades both pinions may be thrown out of gear. This matter of speeding hand cars is important, because for use on grades a high-speed car—that is, a car having a slow-moving lever—requires so much force applied to the lever to move the car at all that it sometimes becomes easier to walk and push the car than to propel it; whereas, on the level, with a slow-speed car—which means one having a fast-moving lever—the wind and sweat are taken out of men in rapidly bending the back, without being able to attain good speed. A road having long stretches of both level track and grades ought, in procuring hand cars for its section crews, to get for each section that hand car which is best suited to the grades on it, and thus save much time for the company and much unnecessary labor for its men.

For men of average stature 30½ ins. to center is about the proper hight above the floor of the car to support the shaft or axis which carries the lever. All lost motion in boxes and keys should be carefully taken up. As it is difficult to keep a tight key between crank shaft and speed wheel, the wheel should be cast with a wide spoke carrying two lugs, between which the crank is fitted and held independently of the key in the hub, as shown by Engraving *A*, Fig. 309. On Buda hand cars there is a set screw in one of these lugs to tighten up on the crank when the parts become worn. The oil holes and tubes should be arranged where they can be easily got at and they should be provided with dust guards or flaps of leather or painted canvas, or wire nails may be stuck into them to keep the dirt out. The main axle boxes should be provided with packing, so as to hold the oil up to the axles, underneath. In winter time a small amount of kerosene may be mixed with the black oil to keep it properly thinned. The bearings holding the main axle from springing at the pinion should be fixed so as to slide up when an unusual weight is bearing down on the floor above it; otherwise that axle may sometimes become cramped and prevented from turning truly. One wheel on the axle not driven should be loose, so that the car may be easily turned by lifting one end and swinging it around. The loose wheel also reduces the resistance to rolling motion on curves, and on tangents too, if there be an inequality in the circumferences of the two wheels. The best way to secure the wheels to the axles and the pinion gear to the driving axle is by a tapering fit, with jam nuts, screwed against the hub. The method of fitting by driving a key usually forces the wheel or gear out of center with the axle. An eccentric pinion is known by the sound thereof, the harsh music pealing forth to the tune of once each revolution. All available space inside the gallows frame should be used for a box to carry the oil can, a few bolts, spikes, track chisels, etc. A small, long box is sometimes placed alongside the gallows frame, lengthwise the car, for keeping flags dry and out of the way; otherwise flags ought to be carried in a tin case. Hand irons should be placed along the side of the top pieces of the gallows frame, so that shovels, hammers, picks, etc., can be stood up inside them and be out of the way of the men's feet. The brake should be at the side, because if the car is running fast the rapid motion of the lever will not permit a man to throw his full weight upon an end brake. The brake blocks should be faced with leather, so as to take good hold, and everything connected with the brake should be maintained in good condition. In a long experience with hand cars, I have always thought there should be two brakes —one on each side—so as to be able to get "quick action" in cases of emergency, which will happen occasionally. A chain and lock should be carried for locking the car in case it should be left standing without any of the section hands near. This chain gives least bother if hung by a link, near its middle, to a staple or eye bolt in the side of the car close by one of the wheels, so that when not used it may hang out of the way.

The knack of running a hand car fast is to get force to the handles, and this cannot be done as easily by trying to bear down and pull up hard against them while they are moving rapidly as it can by using moderate strength and trying to make the hands race with the handle. In this way more force can be put to the lever while it is moving rapidly than by trying to exert so much strength. When the rails are covered with frost and the driver wheels slip it helps matters considerably to increase the weight on these wheels for traction, and this may be done by having most of the men stand on and toward that end of the car, running the loose wheels ahead, to clear the rail of frost and give better traction to the drivers. The loss of traction from frost on the rails is very provoking, sometimes, and is frequently the cause of much delay in getting to work. It might be a good plan to place sprocket wheels on the axles of hand cars, to be coupled up with sprocket chain temporarily, during the frosty season, in order to obtain four wheels for traction.

Hand cars are often needlessly smashed by being run into by irregular trains. All irregular trains should blow the whistle before rounding each curve. When running a hand car either against or before a train which is late or a train which may be expected at any moment, it is well while rounding curves to keep a man running between the hand car and the train, as far away as he can see the hand car, so that he may signal the latter in case the train comes near. At least one man of a hand car crew should always face the rear and keep a lookout for trains. Hand cars run at night or through dark tunnels should display a white light in front and a red light at the rear. During foggy weather it is dangerous to attempt to run hand cars, for there is no practicable way to protect the car that will permit it to run faster than a walk, and even then there is considerable risk. On some roads the foremen are forbidden to take hand cars out in a heavy fog. On other roads they are instructed not to take the car out in fogs if the destination is less than a mile distant. Hand-car platforms should be built at intervals of one fifth to one third mile along the section, to save time and trouble in taking off the car when it is loaded with tools, and also to provide places at which to take off the car in cases of emergency. In long cuts it is well to dig away, if necessary to make room, about the middle of the cut and put in one of these platforms. The platform may consist simply of two wooden rails, blocked up with a pile or cribbing of old ties, if on a fill, running away from the track at a slightly descending grade far enough to give clearance. Hand car "turnouts" of earth filling, covered with a shallow layer of gravel or cinders, are more convenient than rail or timber platforms, and on shallow embankments they are to be recommended. To improve the appearance, as well as to prevent the filling from being tramped down, the slopes are sometimes paved with cobble stones. The standard earth turnout of the Southern Pacific Co. is 9 ft. wide and extends 11 ft. from the rail. It is well to lay a covering of inch boards over the ties inside the rails, opposite the platform or turnout, so as to facilitate turning the car; the boards should be well nailed to the ties. It is a good plan to habitually take the car off the track, when working in one vicinity for any considerable length of time, whether a train is expected soon or not. If the car is set off on uneven ground the wheel which does not have a bearing should be blocked up. For hand cars of ordinary weight, portable turntables or "jiggers" used opposite tool houses for turning the car are usually more bother than they are worth. It is more convenient and expeditious to turn the car by hand, and for this purpose the track, between the rails, opposite the tool house should be planked over with 2-in. plank well nailed or spiked fast, for a distance of 8 or 10 ft. In putting a hand car off or on track that is not filled in, the car should be lifted; an attempt to turn it on the ties may result in a wrenched wheel or sprung axle. It is frequent observation that the wear and tear on hand cars in putting them on and taking them off the track is greater than in any other way.

At all times when running the hand car the following tools should be carried: shovel, claw bar, hammer, gage, wrench, 2 chisels, flags, spare bolts and spikes, plugs and oil can; and in a wooded country an ax. These tools will answer in almost any emergency and do not make much of a load to carry. On railroads one can never know what moment a call for men will come, and for this reason the tools referred to should always be near by. It is also a good plan to have a small wooden box, with a cover, conveniently fitted up inside to hold such tools as hack saws and frame, hand cold chisels, small hammer, monkey wrench, assortment of wire nails and spikes, fence staples, files, hand punch, a piece of waste, and a few of such other minor articles as may suggest themselves. If not kept in some like system such tools, which are often very much needed, will not be at hand half of the time, and if habitually thrown into the open box inside the gallows frame together with spikes, bolts, etc., they will be either broken or daubed with oil when needed. Rails and heavy loads of ties should not be carried on hand cars for a common thing, as cars soon get broken down if so used.

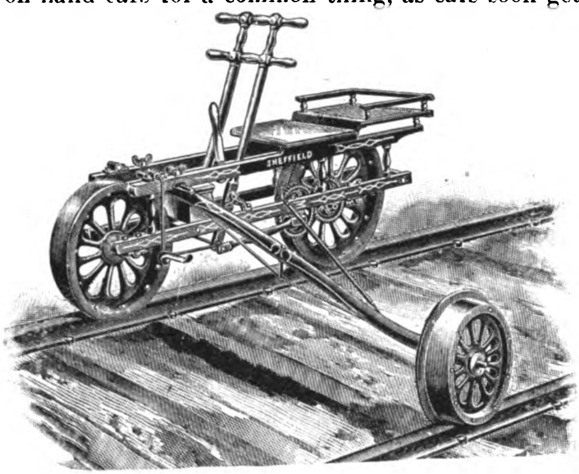


Fig. 341.—Sheffield Velocipede Car.

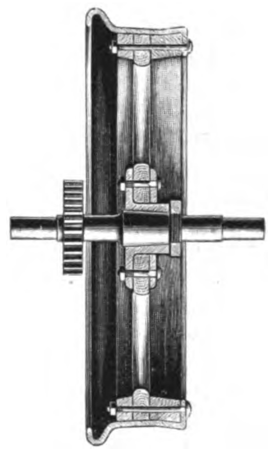


Fig. 342.

For sections on heavy mountain grades push cars may be substituted for hand cars, as when moving up grade the men must walk and push the car, and when coming down grade a push car will coast as fast as a hand car. If the push car is braked with a handspike it is a good plan to carry two of them, so as to have one to fall back upon in case the one in service falls out of the hand of the man applying it. In running a hand car down a mountain grade where the view is clear along the valley below, the experience in looking for trains coming up is similar in one respect to looking for steamships at sea—the heavy black smoke of the hard-working engine is usually the first indication.

The proper care of hand cars is an important consideration in section work, and must be directed by some degree of intelligence, especially with respect to the adjustment of the bracing and truss rods. A car may readily be spoiled for easy running by an ignorant use of the monkey wrench in straining on the brace rods. All of the rods should be kept in even tension and they should not be drawn up so tightly as to bend portions of the platform or frame. Particularly is this rule applicable to the diagonal bracing and vertical rods in the gallows frame. A heavy strain on the vertical rods will give the platform an upward curve in the middle and an uneven tension in the diagonal rods will twist the frame out of shape and warp the platform, causing the bearings to cramp the shafts and axles and make the car run hard. Such ill usage of machinery is inexcusable and will not occur with men possessed with ordinary powers of observation; but it sometimes does occur, and for this reason some manufacturers have been led to dispense with the adjustable feature and design a gallows frame intended to be rigid enough without diagonal rods or other devices which can be tampered with. One of the Buda designs of hand cars has an angle-iron gallows frame without adjustable bracing.

Track Velocipedes.—Hand cars for light service, capable of carrying one or two, or perhaps three, persons, are made in many forms. Such cars are in demand among track forces principally for the use of watchmen, for track inspection and for carrying switch lamps; to telegraph linemen they are indispensable. Perhaps the best known form is the 3-wheel car with one or two seats, commonly known as a velocipede car or "speeder," shown in Figure 341. The rider sits over the rail, on one side of the track, and operates the car by lever and treadle, using both hands and feet. As they are shown in the figures there is but one seat, the cover over the frame in rear of the operator being enclosed by a low guard, forming a receptacle for carrying tools, lunch pail, packages, etc. In another pattern of Sheffield car this guard is dispensed with and a seat is provided for a second person, with a foot rest, the latter hanging on the inner side of the frame. Some vehicles of this kind (used principally by telegraph linemen) are

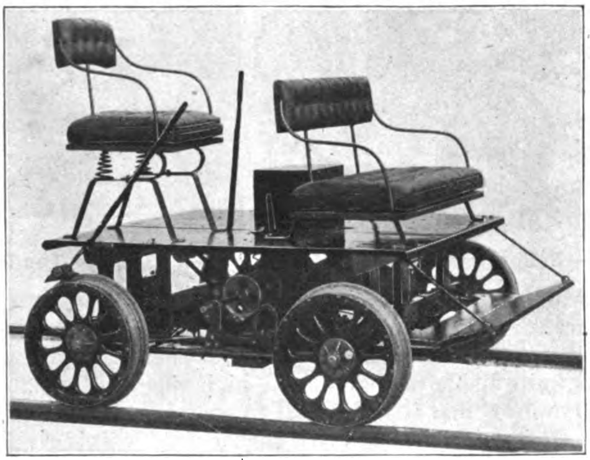


Fig. 343—Hartley and Teeter Gasoline Motor Car.

made double seated, so that two operators may work on the same lever and treadles. The two seats are arranged either in tandem—one seat forward of the lever and the other in rear of it—or side by side, in which case the two operators sit at a balance on either side of the car frame, on a plank swung across the frame in rear of the lever. If the riders are not of similar avoirdupois the heavier man should sit on the inside end of the plank. In the latter arrangement both riders face the front; in the former, one faces the front and the other the rear, and in this respect it is the more desirable arrangement. The diameter of the wheels on the rider's side is usually 17 ins. The third wheel, known as the guide wheel, is made about 12 ins. in diameter and runs opposite the front wheel on the rider's side, at the end of a braced cross arm. For convenience of shipment by train this arm is made detachable and may be folded against the side of the frame when taken down. As the guide wheel carries but little weight it would easily mount the outside rail of curves if the car was permitted to run freely from side to side of the track. One way of providing against derailment is to give the car a side draft toward the rider's side, by setting either the guide wheel or the front wheel (usually the front wheel)to lead slightly that way in running; and another arrangement is to make the treads of the forward wheel and driver slightly concave, or beaded on the outer side. Figure 342 shows the construction of the wheel for the Sheffield 3-wheel cars. The wheel center is of wood and the tire is steel, concaved.

Three-wheel cars for one operator, of the forms above considered, weigh from 130 to 165 lbs. and are easily lifted to or from the track by one man. The lightest car made is the No. 16 Sheffield velocipede car, weighing but 50 lbs. It has 3 rubber-tired wheels with wire spokes, bicycle style, and a frame of seamless steel tubing. The propelling mechanism consists of lever, with treadles at the bottom end, sprocket wheel and chain. The car is equipped with anti-friction bearings. Double-seated cars used by telegraph linemen have a shallow box on the cross arm for carrying wire, tools, etc., and weigh 175 to 200 lbs.

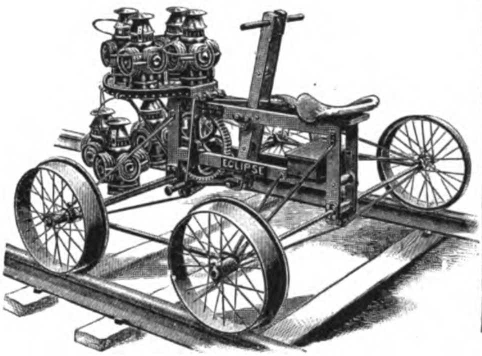


Fig. 344.—Eclipse Hand Car.

Fig. 344 A.—The Pony Car.

The 3-wheel car is very serviceable and is used in greater numbers, perhaps, than any other form of light car. It cannot be run backward, however, without running off the track, and when the rails are frosty the rear wheel is quite liable to slide off the high side of curves. It should be understood, however, that it is difficult to operate any form of hand car on frosty rails. It is said that cars with rubber-tired wheels give best satisfaction in this respect. A slight variation in the set of either wheel on the rider's side will run a 3-wheel car off the track. The advantages claimed for 4-wheel velocipede cars are that the wheels cannot slide off or swing off the rails and that the rider sits over the middle of the track where he can get a better view of both rails and their fastenings than when sitting over one of the rails, as on a 3-wheel vehicle. Moreover, the rider of the four-wheeler need pay no attention to the poise of his body, whereas the rider of the three-wheeler must be somewhat careful of his movements: by leaning heavily toward the outside he will tip the car over, and on curves he cautiously leans toward the middle of the track from force of habit. On the other hand the four-wheeler is cumbersome for shipment in the baggage car, will not carry so heavy a load, and is not so conveniently arranged for taking on an extra load.

The Eclipse velocipede car is a light four-wheeler with saddles for one or two riders, as desired. Its weight is 85 lbs. In Fig. 344 it is shown as rigged for carrying switch lamps. It is equipped with ball and roller bearings and has trussed axles and frame, with diagonal adjustment rods for keeping the wheels in tram. The wheels have rubber tires, to insure noise-less running, and the brake is applied to the drive axle by a lever just in front of the seat. The Hartley & Teeter 4-wheel car (Fig. 345) for a single rider weighs but 60 lbs. The frame is of bicycle tubing, propulsion is by foot gear of the bicycle kind, and the rider steadies himself by leaning forward on bicycle handles. The wheels (17 ins. in diameter) are faced with a pebbled rubber band $^3/_{16}$ in. thick, cemented on. The car has ball bearings and the brake, of the band pattern, is applied to a friction wheel beside the sprocket wheel on the rear axle. The brake lever is operated by hand. Its position being just under the handle bars, at the side of the head piece of the frame, it does not show in the figure. The car has a luggage basket and tool pouch. The car is also made with two seats, arranged side by side, in which form it weighs 75 lbs. To either of these cars an extra front seat, made of bent three-ply veneer and supported by a strong steel frame, may be attached to the framing, immediately above the front axle. This seat adds only 15 lbs. to the weight of the car and is a popular attachment, inasmuch as it increases the carrying capacity of the car and affords a position for a person disinclined to work his passage.

Fig. 345.—Hartley & Teeter Hand Car.

For purely inspection purposes light hand cars are arranged in many ways not stated above. On 4-wheel cars there is sometimes a seat extending across the car in front of a bobtailed lever or walking beam; in other cases swing chairs are mounted on supports at either side of the car, forward of the lever. Hand cars have been arranged with canopy tops and in other ways too numerous to mention. Twelve or 15 miles per hour, on level track, is good speed with hand-propelled cars, although a much higher rate may be made in short spurts while racing.

As the propulsion of cars by hand is not without labor, the "mother of invention" has come to the rescue with small steam and gasoline engines, and even with sails. The Sheffield gasoline motor car is shown in Fig. 346. In construction the car is essentially a Sheffield velocipede car with the frame slightly changed to suit the requirements of power installation. The device which furnishes the motive power is essentially a double gasoline engine, the connecting rods from the engine cylinders operating directly on cranks at either end of the axle of the driving wheel, as shown, the shield or foot guard having been removed to exhibit this feature. While it will not be necessary to go into all the details of explaining the operation of the engine (such being similar to gas engines ordinarily in use), it may be well to explain that the control of the car is effected by three levers or devices—one having to do with the quantity of oil supplied; another with the quantity of air supplied, which determines the number of explosions in relation to the number of strokes; and a third lever which controls the igniting spark. In starting, the car is given a push and the

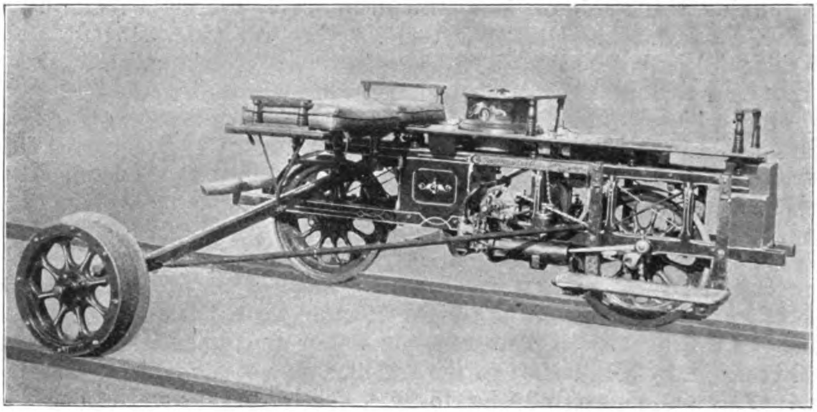


Fig. 346.—Sheffield Gasoline Motor Velocipede Car.

oil is turned on and ignited by the spark, after which the speed can be regulated at will. The igniting spark is furnished by a sealed battery stored under the seat of the car. There are three seats on the car, arranged for as many riders, the operator sitting on the rear seat within reach of the controlling apparatus. Brakes are provided for both the front and rear wheels, so that the car is constantly under the control of the operator and the person or persons riding in front. This car weighs 275 lbs., can readily be placed on, or removed from, the track by one man, and is capable of running 25 or 30 miles per hour, if the rider so desires.

There are several designs of gasoline motor cars built with four wheels and a platform, with a seat extending across the front end. On the Hartley & Teeter car (Fig. 343) the gasoline engine, of 2½ horse power, drives the rear axle, and the operator sits in a chair at a rear corner. The car is equipped with gear for two speeds, the slower for use in ascending heavy grades, and reversing gear is sometimes provided. The motor is started with a starting crank and then thrown in gear with the car axle. The car starts from a standstill without pushing, and can be stopped without stopping the motor. The weight is 500 lbs. The tanks hold enough gasoline to run the car 175 miles.

134. Push Cars.—Besides the hand car (the propulsion hand car) the section outfit includes two kinds of slow-speed vehicles known as the push car and the wheelbarrow. The former is also called a "truck," or "rubble car," and is used for carrying materials, such as rails, ties, ballast and other supplies too heavy or too bulky to carry on the hand car. Owing to the heavier loads it is required to carry it must necessarily be made stronger than the hand car. The severest test on the car is a full load of rails, because they overhang the car and ride with a teetering motion. For ordinary section work the axles should be of steel, 1¾ ins. in diameter, and to save lifting too high in loading, the wheels should be lower than ordinary hand car wheels. Sixteen inches is about the right diameter, being a compromise between high lifting and hard running; for the smaller the wheel diameter the harder the car runs. There is another important advantage with the low push car not always taken into consideration, and that is the facility with which low cars can be propelled by "kicking." When the car is running light or empty four men can sit at the corners of the car and send it along at good speed by kicking against the ends of the ties. A high platform places the men out of convenient reach of the ties, so that the operation of kicking becomes extremely fatiguing, and practically of no effect as a motive power.

The length of wheel base or distance between the axles should be about 4½ ft. for a 7-ft. car. The platform is usually made 5½ ft. wide, extending over the wheels; and pieces of 2x½-in. strap iron should be placed across the ends to protect them against being cut into when the car is loaded with rails. The platform of the car is usually formed upon two 2x6-in. side sills, to which are bolted the journal bearings, and across which are placed the pieces upon which the floor is laid. As a rule these cross pieces are notched in the ends, where they fit over the side sills, as shown by sketch in Fig. 347. This is a bad arrangement, for the piece is almost sure to split, as indicated by the heavy line, when the first heavy load of rails is carried, and if cross-grained (as it frequently is) the truck is greatly weakened. It is better to make up this 2x6-in. piece with a straight-grained piece of 2x4 and one of 2x2, bolted together near the ends. The lower part is needed to act as a strut between the side sills. To prevent spreading of the side sills under heavy load they are usually held against the struts by long bolts passing entirely across the frame, and to keep the car body properly squared truss rods are sometimes run between diagonally opposite corners. Most push cars turned out by manufacturers, have the end cross timbers strengthened by truss rods. To keep dirt out of the bearings the axle boxes may be shielded with flaps of leather or painted canvas.

Fig. 347.—Improper Form of Cross Piece for Push Car.

The weight of the car can be got down to 450 or 500 lbs. At least four men are required to lift such a car bodily and carry it to or from the track. The ends of the side sills are usually made to project beyond the car and are rounded off for handles. Two handles at each end of the car are enough, but a horizontal hand iron at the middle of each end cross piece affords opportunity for a third man at each end, in lifting the car, and is a serviceable attachment. To facilitate handling the car with less than four men there should be a loose wheel on one or both axles, so that the car may be easily turned in the track. For a small crew the best form of push car is one having the body detachable from the axles, so that two men can easily put it on or off the track in sections. With this form of car, however, the boxes cannot be packed and the oiling must be attended to frequently. For trucking cinders or other ballast material the car body may be provided with stake pockets and removable side and end boards, which are usually made about 12 ins. high. For quickly dumping loads when working on main track, dumping beds or platforms are sometimes provided for push cars. This device consists of a platform of boards nailed across a half-round stick and sided up on three sides. The platform (or shallow three-sided box) is about 8 ft. long and 6 or 7 ft. wide, and it is placed for service with the rounded support (which runs longitudinally under the center of the platform) near the side of the car, with the open side of the platform or box outward. The platform is dumped by tilting it over the side of the car. Push cars, when not in use, should be kept at a safe distance from the track and the wheels should be secured by chain and lock. Neither push cars nor hand cars should be taken off the track and left where they will obstruct highways.

Push cars to be used on grades should by all means be provided with a strong brake at the side, for when such a car with a heavy load gets beyond control, on a grade of any consequence, it runs away like the boy's yoke of oxen—"powerful stout." A Sheffield push car with brake rigging is shown in Fig. 348. The weight of the car complete is 490 lbs. Brake blocks are applied to all of the wheels. In a device of this kind the brake lever should drop down out of the way of loading, when not in use; or the lever might consist of handle and socket, as arranged for a track jack. When the car is not equipped in some such way it is braked by taking a pry over a wheel with a handspike, through a hole in the decking; but the application of braking power to one wheel only has a tendency to wrench the car out of shape and the method interferes to some extent with the loading.

Any man who has helped to kick a push car some considerable distance must have been impressed with the desirability for some speedier and easier means of locomotion. The idea of providing hand cars with a detachable gallows frame and lever, by the removal of which the vehicle can be changed to a push car, and vice versa, has been put into practice in two or three different arrangements or designs. The construction of a certain pattern of Cyrus Roberts hand cars provides for ready conversion into push cars. All of the driving gearing is located beneath the decking or floor and the gallows frame is not built in with the platform, but constitutes an independent framework which is held to place by a "clamping bolt," when in position to propel the car. All that is required to remove the gallows frame and make the change is to loosen the clamping bolt and disconnect a turnbuckle on the pitman or connecting rod. On another combination car known

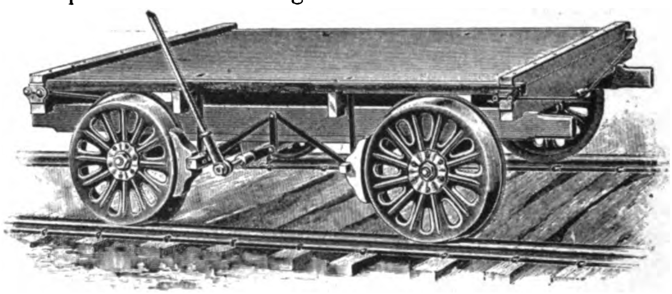


Fig. 348.—Sheffield Push Car With Brake.

as the Imperial pattern the support for the operating lever consists of a single upright standard fitting into a 3-in. square hole through a 9-in. iron plate and then into a socket under the deck of the car secured by brace rods. The lower end of this standard is tapered on all four sides, so that the tendency from wear of parts is to fit the standard more firmly into the iron base. For the connection of the driving rod with the large gear or "speed" wheel the latter is provided with four holes, so that in event of wear to one of them there are still three others available. The operation of removing or replacing the supporting standard and driving rod is a momentary affair, as there are no bolts or nuts to be removed, requiring time, and nothing to be misplaced or lost. Another interesting feature of the car is an arrangement whereby the position of the connecting rod can be changed on the handle bar or lever, so as to regulate the leverage according to the load on the car or the grade of the track. This position of the connecting rod can be changed by simply adjusting a screw, while the car is in motion, if desirable. By this means of adjustment the handles may be made to describe an arc of only 8 or 9 ins. on level track, where quick movement is essential to speed, or 18 to 20 ins. on heavy grade, where leverage is required rather than quick movement.

There is a handy little push-car vehicle known as the "Pony" car, which is particularly convenient for carrying light loads of ties, poles, lumber, tools, etc. in busy yards or wherever trains are frequent. It consists of a light frame on two double-flanged wheels arranged in tandem, to run on one rail (Fig. 344A). It is held in balance and pushed by a lever or handspike at the middle, and in case of emergency the car and its load can be quickly overturned, outside the rail, so as to put it clear of the track.

135. Other Tools.—The ax should be double-bitted. At least one bit is bound to see hard usage, but if there are two it is possible that one of them may be kept in good condition. A single-bitted ax with trackmen will usually be found in the same condition as a boy's jackknife—always dull—and it comes so handy for use as a wedge that the head is usually found badly battered from hammer blows. A bush hook or brush ax (Engraving *R,* Fig. 295) is a stout hooked blade carrying a strap and shank to which a single-bitted ax handle can be fitted. It is useful in cutting brush too heavy for the scythe, but too light for the ordinary ax. Brush scythes should be short, wide, and heavy. The brush scythe is a more suitable tool for cutting sprouts and small brush than is the brush ax. For grass also the scythe should be rather heavier than the ordinary grass scythe used by farmers, owing to the heavy weeds which usually grow along track. The snaths should be stout and interchangeable with either the brush scythe or the grass scythe. The list of tools for a section outfit (§ 116) includes two adzes. The necessity for two tools of this kind is that one is required for old ties and in rough work, where it cannot very well be kept sharp or in the best of condition all of the time. The other may be used exclusively on new ties and in new work, and in this way can be kept in good condition. The crosscut saw should have a wooden guard to fit against the teeth, to save them from being injured or dulled while it is being carried on the hand car.

A curving hook is made by bending a bar of inch round iron, 3 ft. long, into U-shape, and then bending about 6 ins. of each leg of the "U" at right angles, to hook under the base of the rail, turning up the extreme ends of the hooks about an inch to keep them from pulling off. Two flat files of medium size, one fine and the other coarse, and one round file, are often useful tools to have on hand.

If good water is handy along the section, a 3-gallon, heavy, galvanized pail, and two dippers or cups are needed. The best vessel for carrying water any considerable length of time is a stone jug covered with two or three layers of coarse canvas or gunny cloth. By wetting this outside covering the evaporation of the water from it will cool the water in the jug. Railway section hands, above all other men, are inveterate drinkers of water, and it requires a large jug indeed to hold a supply of water sufficient to last three or four of them during a hot day. Where water is scarce along the line a wooden keg, with iron handles, holding 15 or 20 gallons, is sometimes used. Another water receptacle used on some roads is a pine box lined with zinc or galvanized iron, leaving an air space between the metal and the sides of the box, for cooling purposes.

The wheelbarrow should have a box large enough to hold a good load. The wheel should be of iron and it should be of rather large diameter, so that the man pushing the barrow can see it (the wheel) over his load when turning corners on running plank, thus necessarily throwing more of the load on the arms than is the case with some wheelbarrows used elsewhere. The large wheel, however, enables the barrow to be easily pushed over a rough way. It is not usual to find on the market wheelbarrows strong enough for railroad service. The most accurate tape line is a steel one, but such is rather too expensive for the usage it would get among most section men. A linen tape with steel or brass strands running through it lengthwise is accurate enough. Such a tape will not stretch, but it will shrink if it gets wet, and care must be taken, therefore, that it is not used in the rain or trailed in wet grass or on wet ground. A 50-ft. tape will answer, and it should be graduated to feet and tenths. The foreman should at all times, while on duty, carry a 2-ft. rule in his pocket.

The plan of straightening angle bars at elbowed joints on curves or exchanging places with the outside and inside splice bars at the joints, to correct the alignment of the rail, is elsewhere referred to. While it is an easy matter to straighten an angle bar bent horizontally, by suspending it between two supports and striking the middle of the bar with a hammer, such method of treatment will not straighten a bar which is surface-bent. Mr. John Wirley, roadmaster with the Lake Shore & Michigan Southern Ry., is the designer of a tool for straightening surface-bent angle bars. The device is in general use on that and other roads with satisfactory results. The right of manufacture being in the hands of the Elkhart Frog & Crossing Works, the tool is commonly known as the Elkhart angle-bar straightener. Briefly, the tool (Fig. 349) consists of a screw clamp and a pair of blocks notched to accommodate the legs of an angle bar in any one of the four positions in which it may be desirable to place the bar for straightening, namely: with the vertical leg of the bar right side up, or upside down; or with the vertical leg lying horizontally and inside up, or outside up. In

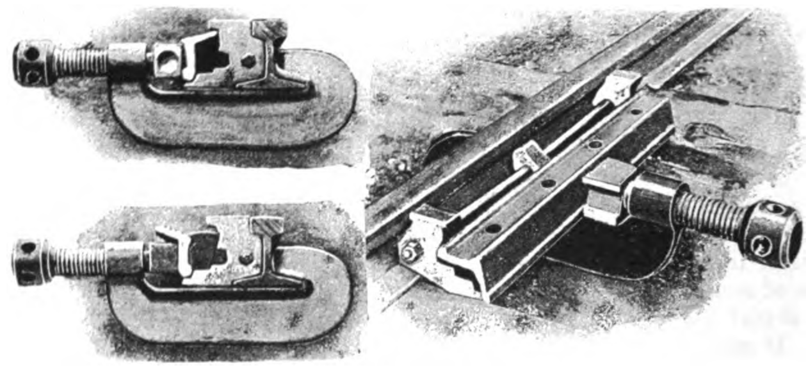


Fig. 349.—Elkhart Angle-Bar Straightener.

straightening a bar the clamp is hooked over the flange of a rail in the track and the blocks or rests for the angle bar are placed against the web of the rail, on the opposite side. The splice bar is then fitted against the blocks and is bent by turning the screw against its middle, as shown in the illustration. It is thus seen that it is possible to straighten the bar when bent in any one of the four ways in which it is possible for an angle bar to become distorted in the track; that is, bent in surface, either up or down; or in alignment, either outward or inward.

136. The Use and Care of Tools.—While the proper use of track tools cannot be said to require skill of the hand to a high degree, still it takes some time for men to learn to use them readily, and a fair degree of intelligence with the exercise of good judgment are essential in order to turn out good work with them. When breaking in new men foremen should insist at the start that they learn to use tools properly, so as to be able to perform a satisfactory amount of work for a fair amount of exertion. A man who can handle all track tools well can make himself quite handy in a good many other occupations. Men should get into the habit of using such tools as the shovel, tamping bar and hammer either handed. It makes the work easier, for to change hands gives a sort of rest; and it also helps to keep the laborer's shoulders even.

Foremen should be held strictly accountable for all the tools intrusted to their care, and they should be made to pay for such as they cannot show up. A good plan to inaugurate is to have a number stamped upon every tool (in Arabic numerals) on some portion of it where it will not be worn off, and a book account or record should be kept of the same from the time the tool is issued from the headquarters until it gets back there again, after being worn out or broken. In this way could be stopped the practice of stealing tools, for which section crews are notorious. A tool found on a section, having a number not corresponding to any charged against that section, or having no number at all, would indicate that that tool has no business there, and unless the number has been effaced it could be returned to the section to which it had been charged; at all events a wrong number or the absence of a number would place the foreman in position to show cause therefor. Each section foreman usually marks his tools in Roman characters to correspond to the number of his section. The practice serves as a ready means of picking out the tool at sight, but is no guard against the dishonesty of other section men, it being an easy matter to take a hammer and cold chisel and add an "I," and "X," or a "V" or to change an "I" to an "X" or to a "V." A method sometimes followed, with the intention of preventing additions to Roman numerals without being detected, is to make a horizontal chisel mark each side the number, thus: —XII—. This method of marking is not, however, invulnerable, for it is an easy matter to change either letter "I" to a "V" without cutting across the horizontal mark, or if, using the present case for illustration, the horizontal chisel marks be lengthened so as to cut across the last "I" of the "XII," then Section XI might claim the tool, since, to all appearances, it would seem as if Section XII had stolen the tool from Section XI and put on an extra "I." A discussion of this matter of changing marks on track tools, somewhat more at length, was published in the Railway and Engineering Review of Feb. 4, 1899, in which I concluded with the following remarks: "There are numerous other ways by which section men get around any system of marking by straight lines. A stolen tool—a bar, for instance—is sometimes purposely bent at the point where the marking is made and then hammered, as if to straighten the bar, thus obliterating the marking. The bar is then thrust into a heap of dirt, or thrown into a mud puddle to rust awhile, and then sent to the shop for repairs. After it comes back any marking may be placed upon it which the new owner chooses, and who else can establish a claim to it? But if all track tools were stamped at headquarters, in Arabic numerals, a stop would be put to the practice of revising the markings on tools, because the would-be counterfeiters would not have the stamps and would not likely go to the trouble of procuring them."

Worn-out tools and those broken beyond repair, no matter in what condition, should always be sent to headquarters, so that when sending new ones in exchange the roadmaster's department may know what became of the old ones, before removing the charge from the books. The division track official should occasionally review the tool reports of his section foremen in search of excess accumulations. A few surplus tools do not seem like a matter of much importance to the foremen, individually, but when such lists are multiplied by the number of all or of a large portion of the sections of a division, the stock becomes a large one and represents a considerable idle investment. Like importance attaches to the practice of storing materials on the various sections, over and above the local requirements. The proper place for storage of tools and track materials is at the division headquarters or some other one point convenient for distribution. If a foreman's outfit of tools is augmented for a temporary increase in the size of his crew, as when taking up some special piece of work, he should, after his crew has been reduced to the normal basis, be required to return the surplus tools to the division storekeeper. In instances of this kind large supplies of tools are liable to be needlessly withheld from service for several years.

137. Tool Houses.—Every section should by all means be provided with a tool house. The practice of keeping tools in a box unprotected from the weather, as is the case on many of the less prosperous roads, is destructive of tools, is inconvenient and is time lost. At the end of the day, when quitting work, men will usually throw the tools into the box in haste, and in this way they are frequently broken or otherwise injured. Many times when a particular tool is wanted it will be found in the bottom of the box, and so the whole pile must be handled over in order to get at it. Tools kept in a box out of doors during wet weather will be found damp or wet much of the time, so that the iron ones will, if not used every day, soon be heavily coated with rust, and wooden handles will decay in short order. Hand cars habitually left out of doors over night deteriorate rapidly; besides, in winter the handles will often be covered with frost or the body with snow, at starting out in the morning. On the other hand, a tool house affords a place where the tools can be kept dry, everything may have its place, and, when wanted, the hand may be placed upon it without having to overhaul a half dozen other things. Such tools as are habitually carried on the hand car, and such tools as are in daily use during the particular season of the year, may remain on the car when it is run into the house at quitting time, thus saving considerable time and labor which otherwise would be expended in loading the car in the morning and unloading it at night.

If possible, the tool house should be so located that in taking the hand car from or to it mornings and evenings the crew will not be hindered by standing trains. As a rule, therefore, it should be outside of the switches, in case there are side-tracks in the vicinity. If the room on the right of way will permit, the house should be far enough from the track to allow the hand car to stand between it and the track, clear of trains, and still leave room for the door to swing. One large door gives less trouble than two smaller ones, and if the house cannot be placed far enough from the track to have a swing door and give the desired clearance, a sliding door or one hung on rollers should be used. The tool house floor should be level with or slightly lower than the top of rail, but not higher; if lower, the track leading into a house having a swing door must be level for a sufficient distance in front of the house to permit the door to swing. If the track leading into the house is of metal rails, they should be laid to slope from the track, so that a hand car left standing without being trigged will not run toward the track. It is a matter of some convenience to have the space between the track and the tool house planked over, the plank laid parallel with the track. In such a case the hand car track running into the house may consist of 2x4-in. wooden rails spiked to the platform. These rails may be omitted within the swing of the door, so that a door may be used which will close tightly at the bottom.

The architecture of a tool house is not very complicated, but as the building is intended to serve a special purpose the proper plans for it require some study. The typical section tool house of American railways is a frame building, oblong in plan and sheathed with upright boards and battens on the outside. The ordinary hight from floor to top of plate is 7 ft., the roof is double pitched, is laid with shingles or sheet metal, and the frame has corner posts, sometimes braced, but no studding. The floor is generally, or should be, laid with 2-in. plank. So far as the purposes of the building are concerned, construction on this order is sufficiently elaborate. The character of the finery that may be added, for the sake of external appearance, depends upon the financial status of the road and concerns more especially the buildings and the traffic departments; the trackman is concerned with other things.

The building should contain ample room for the hand car, push car, grindstone and other tools, and additional space for three or four men to do tinkering work occasionally, as on rainy days, when waiting for the weather to clear up. A building 14x18 ft. in plan just about fulfills these requirements properly. About the smallest tool house heard of is 9x12 ft. in plan. A building of this size affords room to put the hand car and tools under lock and key and that is about all. A small tool house should be placed with the longer side facing the track. The car will then enter through the longer side of the house and it should enter near one end, so that as much clear space as possible may be had between the car and the other end. As a matter of illustration, if the hand-car track enters the long side of a 10x14-ft. house, 18 ins. clear of one end, there will be a clear space of 7x10 ft. in the other end of the house. This is the standard arrangement on the Bessemer & Lake Erie and a number of other roads. With a house of ample size it does not matter so much which side of the building faces the track, providing there is plenty of room on the right of way. If it be the gable end, the hand car or cars can be run farther into the building, thereby leaving more clear space just inside the large door than could be had if the car entered the longer side of the building; and clear space at this point is oftentimes desirable because of the better light, especially during a cloudy or stormy day. In any case the car should enter the building near one side rather than at the middle. In a house of proper size the car should stand not less than 3 ft. clear of the nearest side, so that one may easily walk all the way around it. In a 14x18-ft. house, gable end to the track, this arrangement would leave a clear space 6 ft. wide the length of the house.

Along the sides of the house there should be arranged a few shelves for the small tools, racks for holding bars and other long tools in an upright position, hooks for water-proof clothing, etc. Shovels should be hung from pegs, and all other tools arranged conveniently, instead of being thrown into a heap in the corner. There ought to be small 4-pane windows in three sides of the house, guarded outside by board shutters, and a small work bench, say 18 ins. x 5 ft., made of 3-in. plank, should be placed under one of the windows. The bench should be fitted with a drawer and a 4-in. machinist's vise, or a blacksmith's vise. With the vise should be furnished a drawing knife, which is useful in fitting handles to tools. Attached to the side of the house near another of the windows should be a box or locker with a sloping hinged cover to serve as a writing desk for the foreman and a depository for report blanks, shipping tags, writing materials, small expensive tools, etc. On some roads the tool houses are provided with a small room for the foreman's use, and with a chimney and stove. The latter, in winter time is a desirable affair, from the trackman's standpoint, but generally too comfortable and attractive for profit to the railway company. The surroundings of a tool house are sometimes such that inside privy facilities are desirable, and such may be provided for by partitioning off a small room in one corner.

The standard section tool house of the Toledo, St. Louis & Western R. R. is 13x18 ft. in plan, standing gable end to the track. A 5x13-ft. room is partitioned off in the back end for the foreman's office and each room has two windows. The foreman's room is provided with a stove with a Dickerson cast iron watch box smoke jack on the comb of the roof. The standard section tool house plans of the Erie R. R. are shown as Fig. 350. The house is 12x18 ft. inside and stands with the longer dimension parallel with the track, the hand-car track being at the middle of the house, with a clear space 6½ ft. wide on either side. The plans show a slate roof, but not all the tool houses of the road conform to specifications in this respect. There are windows in the gable ends, with shutters, and a double slide door. Entering the house, there is a covered box for oil and lanterns, at the right side of the door, and under the window on the left side of the house there is a stationary tool box built in with the floor and window studding. The grindstone is properly in front of a window. The rear side of the house is occupied by racks nailed to 2x4-in. studding, as shown in detail. The rack on which tools are laid horizontally consists of three tiers of 2½x1¼-in. chestnut pins 10 ins. apart vertically. The rack from which tools are hung consists of a 2x4-in. piece nailed across four studdings, 5 ft. 10 ins. from the floor, and set with eleven 1⅜-in. round chestnut pegs. Other details of the general construction, of the door guide and rail, of the windows, racks, etc., are clearly shown.

In the ordinary tool house, such tools as scythes, snaths, pails and other extra tools, shims and extra supplies carried in stock, are usually in the way, some being piled up in corners or stored where they will encroach upon room that is needed occasionally for odd jobs that can be done on rainy days. In winter time, especially, it is desirable to store the summer tools in some place where they will be out of the way; otherwise they discommode necessary movements about the tool house, and they are also liable to be broken or injured. This storage room in the Boston & Maine standard tool house is provided for in the attic, overhead. The standard plans provide for two classes of structures, namely single and double tool houses. The plans for the single house are shown as Fig. 351. The building is 24 ft. long and 15½ ft. wide, the longer dimension being parallel with the track. The hand-car track enters the long side of the house,

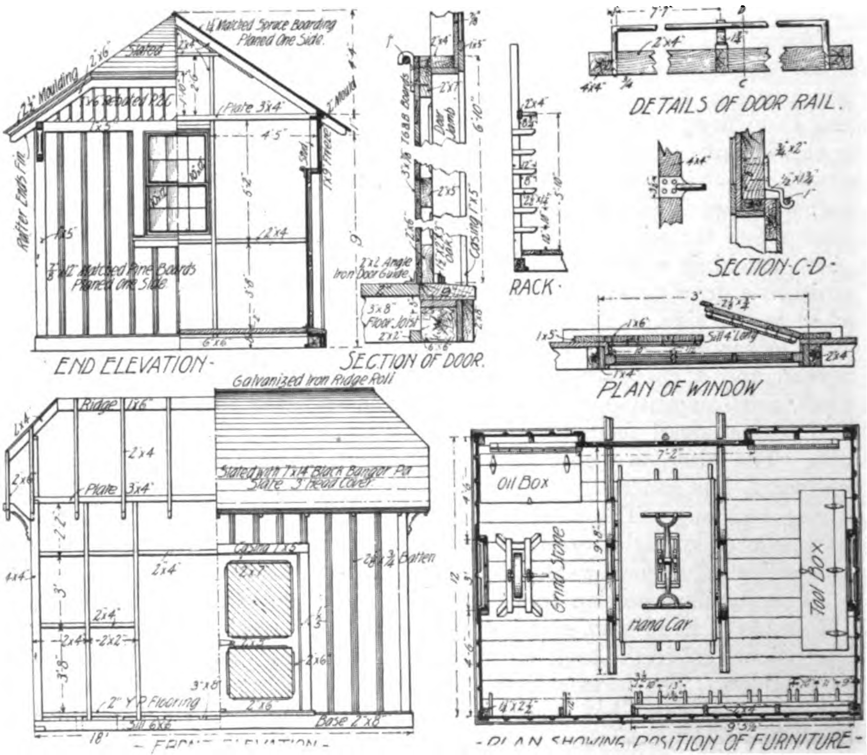


Fig. 350.—Section Tool House, Erie R. R.

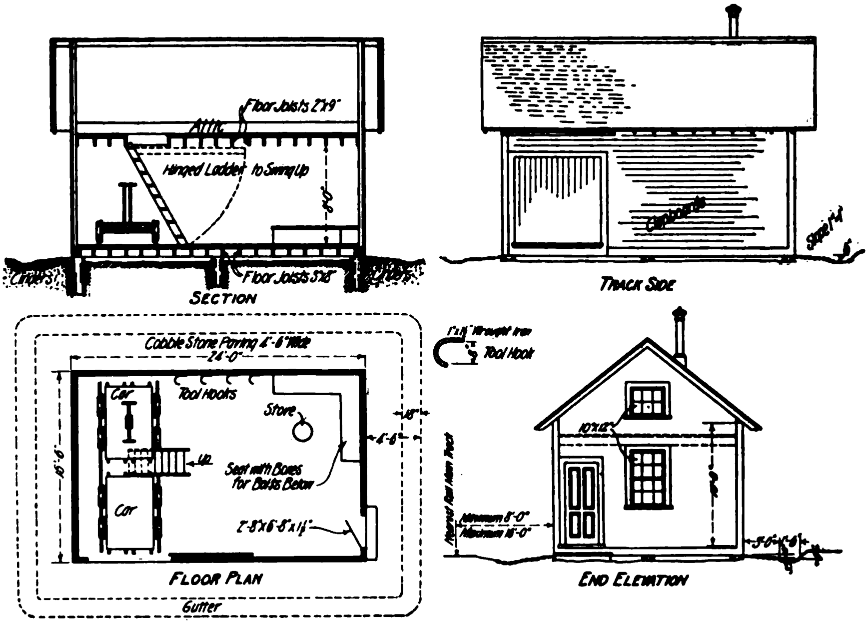


Fig. 351.—Standard Single Section Tool House, Boston & Maine R. R.

near one end, and the house is wide enough to hold a hand-car and push-car, with the door closed. A sliding door is provided at the hand-car entrance, and at the other end of the house there is a swing door of usual size. There is a chimney for a stove and in the corner of the house, near the location for the stove, there are seats arranged, with boxes underneath for holding bolts, spikes, etc. The first story is 8 ft. high, from the floor to the under side of the joists of the second floor. Access to the attic is by means of a ladder hinged at the top, so that it may be swung up out of the way. Other details and dimensions are made clear in the illustration. The standard double section tool house is shown in Fig. 351A. It is 40 ft. long and 13 ft. wide, with a 12x14-ft tool room at either end. Between

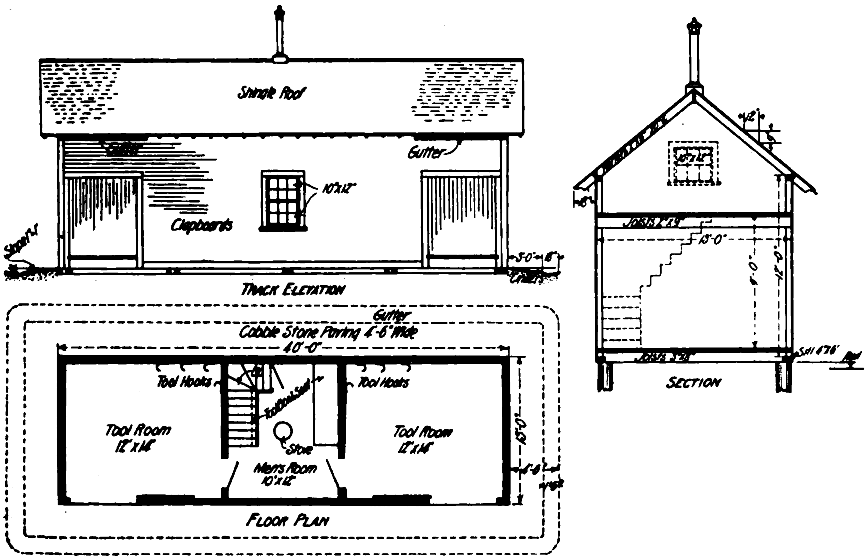


Fig. 351 A.—Standard Double Section Tool House, Boston & Maine R. R.

these two tool rooms there is a 10x12-ft. room for the men to sit in. There is a window in either side, a stove and a conveniently arranged seat. The entrance to the attic is by stairs leading up from this room. This building is higher than the single section house, the studdings being 12 ft. high. The house is well lighted with windows at the gable ends and at the back side in each room.

The plans for each class of building show a strip of cobblestone paving 4½ ft. wide extending entirely around the house, with a 1½-ft. gutter 3 ft. from the house. Wherever the situation permits this pavement is laid and painted with Aquol paint. Some of the houses have small desks, and some have closets. A feature of the design that is commendable, in each case, is the generous provision for working space and storage room.

The floor of a tool house should be swept occasionally. Spare bolts, spikes, nut locks, etc., should be kept in boxes or kegs, and other supplies in neat piles, each kind by itself. A quantity of spikes, bolts, angle bars, switch rods (where there are stub switches), and other supplies commonly used in track repairs, should always be kept on hand in the tool house. During winter time, scythes, snaths, and such tools as will not be used, should be stored overhead, where they will be out of the way. Space for such purposes may be had next the rafters by laying boards on the plates, across the corners of the house. When storing away scythes in such places the blades should be taken from the snaths. Lanterns necessary for use as night signals should be kept filled and cleaned and otherwise in good condition, at all times, and oil cans, unless otherwise specially provided for, should be set in a shallow box or wooden tray filled with sand. Locks for hand cars and tool houses should not be the regulation switch lock, else trainmen and others having switch keys may help themselves. In cases of emergency on railroads there is never any trouble about opening any kind of a lock. Scrap must be stored outside the tool house, and on some roads specially constructed bins are built for the purpose. The standard scrap bin of the Southern Pacific Co. is a box 8 ft. square walled up with four layers of old ties halved together at the corners and spiked. The bottom of the box is a layer of old ties, and the interior is partitioned off with walls of old ties toe-nailed to the sides of the box. Two of the compartments, 3x3 ft. each, are used for assortments of track scrap and the other compartment, about 3 ft. x 6 ft. 8 ins., is used for car scrap.

138. Tool Repairs.—Tools should be kept in good repair. It seems unnecessary that this should be said, yet how many foremen are negligent of so obvious a duty! And then there are foremen—and a goodly number, too—who withhold tools from the repair shop longer than they should, out of fear that seemingly frequent repair bills charged against their sections may in some way affect their standing, or possibly their tenure of position. Such practice is bad economy for the railway company, because both the quality and quantity of the work turned out by trackmen is in many cases largely dependent upon the condition of the tool used. Possibly some roadmasters are to be blamed for the prevalence of such a foolish notion among their section foremen. At any rate some sticklers for close inspection of track work have put themselves on record as favoring low cost of tool repairs and maintenance of tools as one of the conditions to be considered in awarding prizes or premiums at times of annual inspection. I doubt the wisdom of such a plan, as fear of repair bills incurred might beget the custom of wearing tools beyond the point where they cease to be effective. The manipulations of the trackman are not as delicate as those of some other mechanics, and first-class trackmen will wear out tools faster than some other trackmen; while a tool in the hands of a "rambunctious" man will occasionally meet with an accident. If, however, tools are being frequently and recklessly broken or discarded before they are sufficiently worn, that is another question, and a proper knowledge of the use of tools on the part of the division officer, in connection with a proper system of calling in old tools whenever new ones are forwarded, is a sufficient check against extravagance.

The work of repairing track tools at headquarters should, as far as possible, be managed by one man, who should carefully study the shapes, dimensions, temper, etc., best suited to the tools for their uses. Of course the bulk of the repairing must be done in the blacksmith shop, and the blacksmith should have at his command such aid, whenever needed, as will enable him to keep abreast of his work and return promptly the tools sent to him for repairs. On some roads tools sent for repairs are exchanged at the storeroom for others in good repair, thus facilitating quick return. But such practice necessarily dispenses with any system by which each foreman can identify his own tools, or have them repaired to suit special conditions existing on his section.

There should be a well regulated system of sending tools to and from the repair shops. It is usual to tag the tools, throw them into the baggage car and let them go. In this way tools frequently get lost, delayed, or mixed with those belonging to different section crews, due to tags pulling off, illegible writing, or other cause. Mr. W. B. Parsons, Jr., in his book "Track," suggests that in sending tools to and fro for repairs they should be checked, after the familiar manner of checking baggage. Brass checks, similar to baggage checks, have the number of the section and the station address stamped upon one face of the check and the address of the repair shops upon the reverse face. The check strap is slipped through two slots, in opposite edges of the check plate, so as to cover one face and leave the other face exposed to indicate the address to which the tool or package of tools is going. When the tools are to be returned the strap has simply to be slipped through the check plate from the other side, exposing the address on the reverse face and covering the address not wanted.

In case there are special instructions with reference to the repairs of the tools the foreman should forward a note to the repair shop or blacksmith, stating what is wanted. Such information, if written on a tag attached to the tools, may easily be lost before the tools reach the shops. It might be well, however, to note on a tag that instructions have been sent by separate letter. When sending tools for repairs the foreman should forward a note to the roadmaster, giving a list of the tools sent and the date and train, this note to be kept on file in the roadmaster's office to serve as an aid in tracing the tools, should they for any reason fail to get back. On some roads the foremen are supplied with printed blank forms for com-

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.... R. R. CO.

.... Division.

Station.....................

Date................, 190..

To ....

Roadmaster,

....

I have this day sent on Train No. .... the following tools to the Repair Shops at .... for repairs:

....

....

....

........................, Foreman of Section No. ....

---

municating to the shops and the roadmaster such information as is noted above. One form is gotten up in the style of a card about $3\frac{1}{2}$x5 ins. One side bears the address of the roadmaster, and on the reverse is printed the report blank. The accompanying form is a sample.

Another form similarly worded is addressed to the master mechanic or master blacksmith. On some roads tools sent for repairs are billed by the agent, the same as ordinary freight, but such is not always practicable, since in many cases tools have to be put on at flag stations where there are not facilities for billing or keeping record of freight or baggage.

139. Section Houses.—It is sometimes incumbent upon railway companies to furnish dwellings for their trackmen, especially on some western roads where the distances between settlements are great, and where there could be no inducement for a man to build a house for himself, and, of course, no opportunity to rent one. Under such circumstances it is frequently the case that a station, or at least a flag station, is established, and part of the building is used as quarters for the foreman and crew. Again, since it is important that at least the foreman of the section crew should be within easy call, many railway companies make it a practice to build a house for every section, on the right of way, regardless of opportunities for renting, in order that the foreman may remain near the track while off duty. For well settled districts, however, there are many companies which think it not worth while to furnish section houses, as foremen who are single men usually hire their board and do not care to bother with a house. And then, some foremen choose to own homes of their own in the near vicinity of the track. In such an event a company house might have to stand empty, unless the foreman was required to occupy it—which would not be a good policy to insist upon, for such would partake more of the nature of a system of tenancy than of railroading. The less a railway, or any other, company has to do with the private affairs of its employees the less trouble will the company have, and, as a rule, the more dependence can it place upon its employees. On eastern roads generally the practice of providing quarters for the track employees is not as common as it is in the South and West. Through purchase of land, however, railway companies sometimes come into possession of houses which are rented to track foremen, agents or other employees. Where rent is charged for section houses it is, as a rule, only nominal. Since it is for the company's benefit that the track force, or at least part of it, should be near the track during off hours, it should not be the policy of the company to make profit on its rents. Many companies make no formal charge for rent to the occupants of its section houses, while in other cases no formal charge is made, but an allowance of a few dollars each month is made to such of their foremen as are not furnished with a house, or to foremen who are single men and do not keep house.

A building or dwelling for the use of the trackmen, if owned by the company, is commonly known on American railways by the name "section house," and for convenience it is here treated in the same chapter with tool houses. Such a building is usually a framed structure, roofed with shingles or sheet metal, sheathed on the outside with upright boards and battens or with horizontal weather-boarding, and finished inside with either ceiling or lath and plaster; quite frequently with ceiling, on account of the liability of plaster to crack or loosen from the jarring of trains, if the building is close to the track. A typical section house would probably look something like a one-story building with a double-pitched roof, a small entrance porch in front and an "L" or "T" portion in the rear with reference to the track. The capacity of the house will depend upon the question as to whether it is to be occupied by a single family only, or by a family and a number of boarders. In outlying districts it is customary for the foreman to board part or all of the single men working in his crew. In all cases the section house should afford plenty of room for a family of good size, and it should be two-storied, so that space for sleeping rooms may be had on second floor. Some scetion houses appear as if built on the idea that the occupants need facilities only for eating and sleeping. If the family occupying the house is to live in American style, provision should be made for a sitting room, on ground floor, and to fulfill this requirement the ground plan must usually include four rooms—a kitchen, sitting room, dining room and bed room; although if the kitchen be of good size and the family small, the kitchen and dining room would usually be combined in one; or if the dining room be large and the family small, the same room might easily serve the two purposes of dining room and sitting room. If the surface conditions in the locality will permit, the house should have a cellar, with both outside and inside entrances. If the house is located near a water tank or water station fed by gravity supply, it would be a matter of small expense, and certainly a great convenience, to pipe water into the kitchen. It would probably be best to lead the pipe from some point at about half the depth of the tank instead of from the bottom, such arrangement thereby serving as a water gage to persons who are interested and who are supposed to be responsible for the condition of the feed pipe leading to the tank. If the tank is supplied by pumping, it might be questionable whether the plan of supplying the section house with "running water" would be advisable.

As for the exterior design of the house and the arrangement of the rooms there is, of course, wide latitude for selection. While nothing fancy is required, the house should be comfortable and convenient, for such pro-

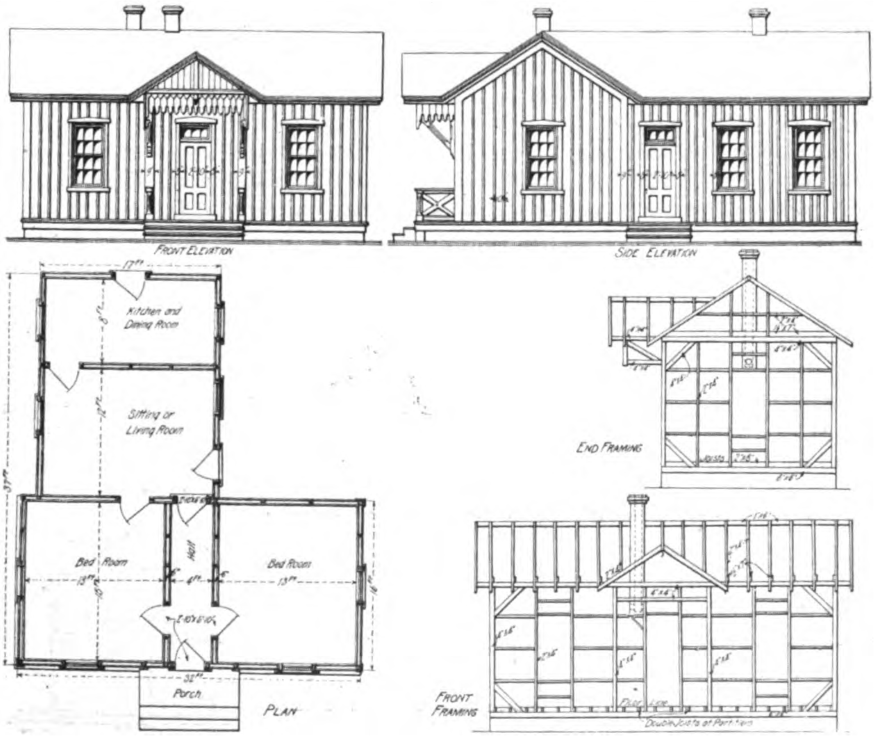


Fig. 352.—Standard Section House, Norfolk & Western R. R.

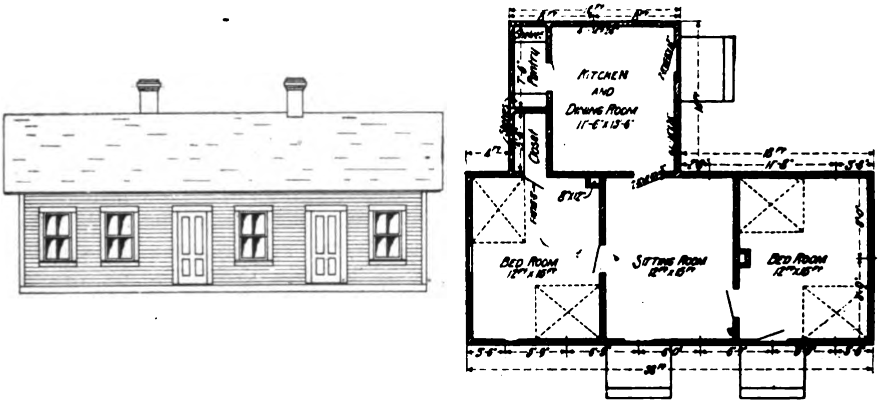


Fig. 353.—One-Story Section House.

vision will be found an inducement in getting a good class of men as foremen. It should be finished off inside with such quality of material that it can be kept clean and homelike. Matters of this kind which please the women folks will work together to encourage the foreman to take a lively interest in his work and to stay where he is. Aside from the arrangement of the rooms with respect to convenience in passing from one to the other, on the part of those engaged in the various duties about the house, the arrangement of the rooms and the openings and entrances thereto should be made with a view to comfort, taking into consideration the climatic conditions of the locality. Thus, for instance, in a hot country good ventilation will require that the house be of open construction, well provided with doors and windows, and so arranged that a draft may be had throughout the house. In a cold country, however, the principal aim should be toward compact construction, so as to economize in the heating arrangements necessary to keep the house warm. In dry portions of the country, as in the Southwest, where water is usually scarce, it is incumbent upon the railway company to provide the house with a cistern of good capacity, for catching rain-water.

In the southern part of the United States the railway section houses are usually one story in hight, with a plentiful supply of windows and doors, wide porches or verandas, and a separate building in the rear to serve as a kitchen. The standard section house of the Savannah, Florida & Western Ry. (Atlantic Coast Line) is designed especially to meet the conditions of a southern climate. The house is a one-story framed building, well spread out, being 33 ft. 6 ins. x 31 ft. in plan, and divided into five rooms. The kitchen is 13x16 ft. in size and is separated from the rear of the main building 15 ft., the two being connected by a covered walk. The house has a high garret, ventilated at the gable ends with louver windows, and a wide porch extends along the entire front of the house. The house is set on brick or stone pillars and the space below the floor is left open, to give

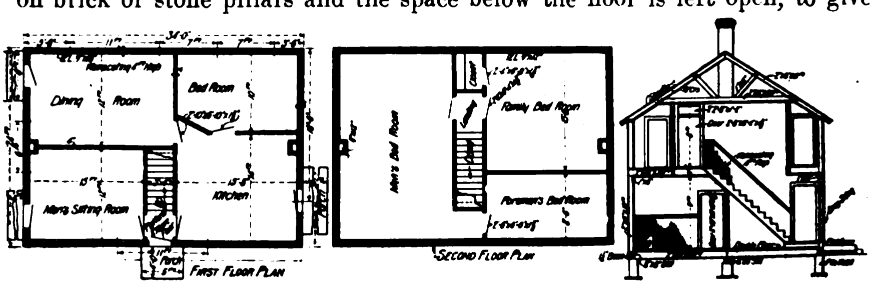


Fig. 354.—Section House, C., R. I. & P. Ry.

ventilation, being guarded at the edge of the building by several strands of barbed wire stretched from pillar to pillar, to prevent animals from getting under the building. The standard section house of the East Tennessee, Virginia & Georgia branch of the Southern Ry. is a one-story, three roomed, L-shaped building with a front and rear porch connected by a hallway through the center of the house, this feature being especially suitable for good ventilation. Many section houses throughout the South are provided with fireplaces in the two principal rooms, which arrangement conduces very much to comfort during chilly weather, in spring and fall, when it is not desirable to keep fires burning continuously throughout the day.

The standard section foreman's house of the Norfolk & Western R. R. is a cheap but neatly arranged one-story building of four rooms, and might be taken to fairly represent a typical southern section house. As shown in Fig. 352, there is a hall leading from the front porch to a sitting or living room in the rear, which also has a door opening to the outside. On either side of the hall there is a 13x15 ft. bed room, and in rear of the sitting room is the kitchen and dining room. In this part of the country it is not usual for the section foremen to board any of their men, and large section houses are not required. Ninety per cent of the section laborers are colored men, who provide a cooking stove, cots or bunks, buy their own sup-

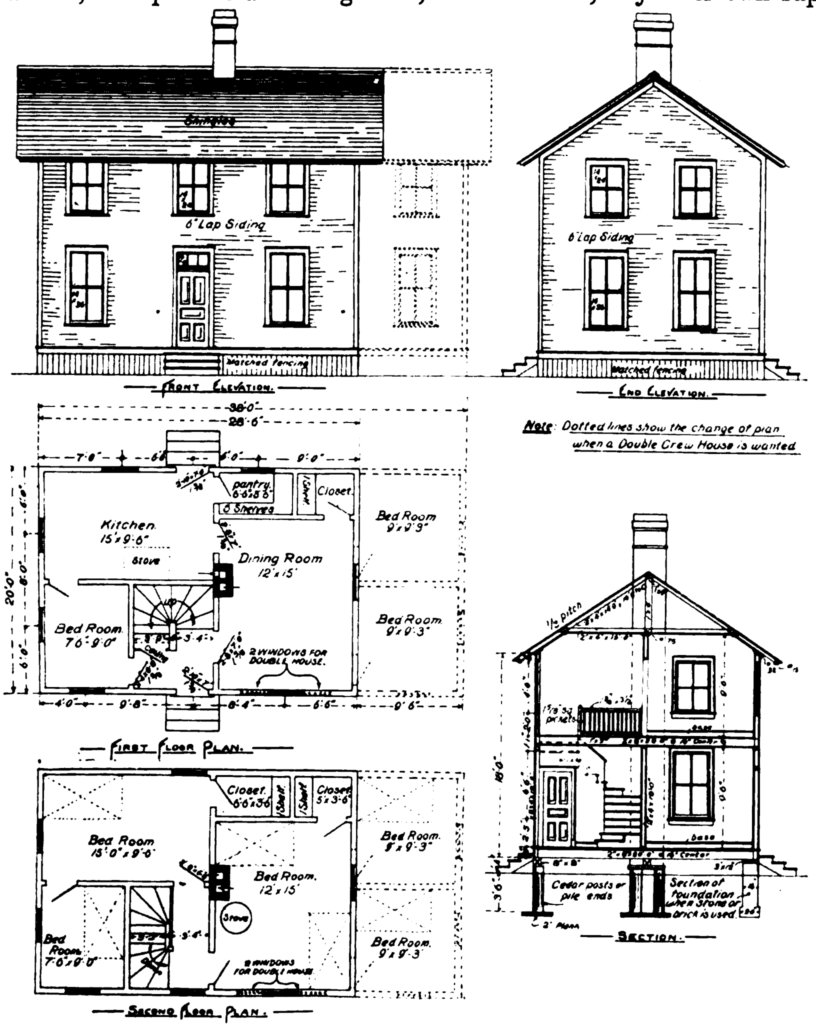


Fig. 355.—Standard Section House, C. M. & St. P. Ry.

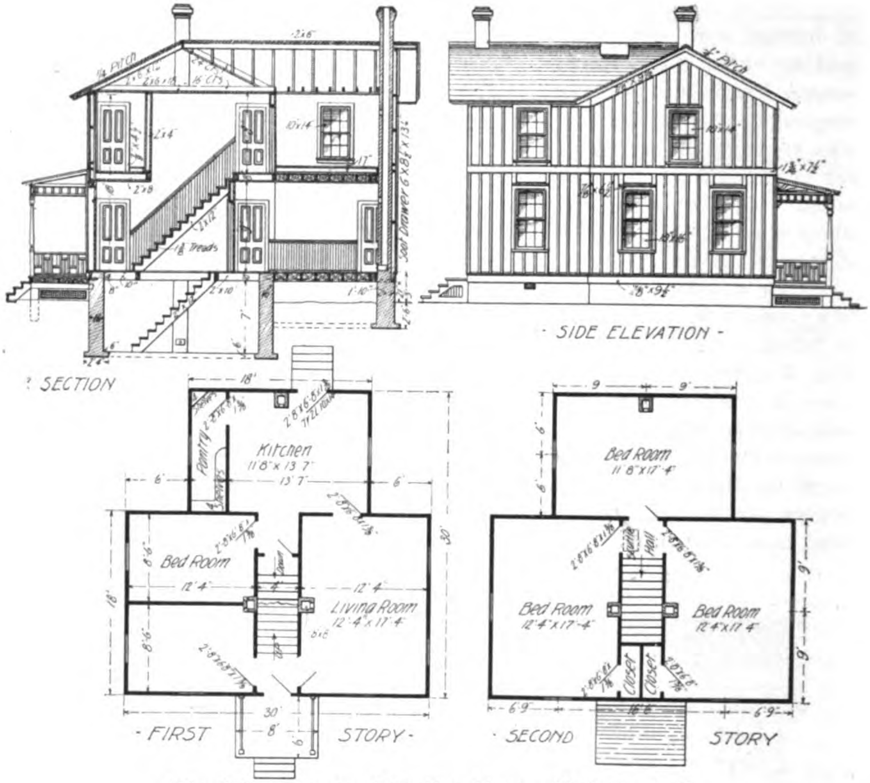


Fig. 356.—Standard Section House, Wabash R. R.

plies and do their own cooking. For their accommodation the railway company provides a one-room house 14x18 ft. in plan, known as the "standard house for section men." There are a door and window in the front side and two windows in the back side. A thimble and a brick chimney extend from the ceiling through the center of the double-pitched roof. To provide for large gangs temporarily employed old box cars are set off. Figure 353 shows the arrangement of a four-room, one-story section house of a western railway. There are three front rooms 12x15 ft. in size, with two front doors, and a kitchen, pantry and closet.

Coming to two-story buildings, Fig. 354 shows the arrangement of the six-room section house of the Nebraska district of the Chicago, Rock Island & Pacific Ry. A noticeable feature is the unusual number of outside doors. Considering the purpose of the rooms as shown, it would seem that a door should be provided between the dining room and men's sitting room, so as to avoid going through the kitchen.

The plans of the standard section house of the Chicago, Milwaukee & St. Paul Ry. are arranged with a view to alternative construction, to suit the size of the crew. For an ordinary or single crew the building has three rooms on first floor and three bed rooms on second floor. There is a convenient arrangement of closets, and a pantry, as shown in Fig. 355. The front door opens into a small hallway at the foot of the stairs leading to the upper floor, from which doors lead to a bed room on one side and the dining room on the other side. The dining room is 12x15 ft. in size and the kitchen 15 ft. x 9 ft. 6 ins. in size, thereby affording good opportunity to combine the kitchen and dining room in one, so as to reserve the large front room for a sitting room. Or the small bed room, which communicates with both the kitchen and hallway, would answer as a dining room for a small family. On the second floor the two family bed rooms communicate with each other and there is only a single door leading to the stairway. The kitchen auxiliaries, in the shape of pantry and shelves, are facilities not usually found in buildings of this kind. The building is 20 ft. x 28 ft. 6 ins., roofed with shingles and sheathed on the outside with 6-in. lap siding. The interior is ceiled. The building rests upon cedar posts or pile ends, or upon a brick or stone wall 16 ins. thick, as conditions determine. When resting upon posts the open space is closed in by matched fencing. The rooms are well lighted, by windows of good size for a building of this class, and in general the interior is conveniently arranged. When constructed for a double crew or for a large number of boarders, a 9½-ft. addition is built on one of the gable ends, thereby increasing the size of the building to 20x38 ft., as shown by the broken lines. This extra space, on both lower and upper floors, is divided into two rooms, each 9 ft. x 9 ft. 3 ins. in size, marked for bed rooms, in the illustration. It is readily seen that by leaving out the partition between these two rooms on the lower floor a room of good size, with three windows, is afforded for a sitting room or for any other desirable purpose. The position of the windows for either the single or the double arrangement is shown in the figure. This double arrangement affords on the upper floor four single bed rooms and one double bed room. The structure is designed with an idea to economize material, and it forms what might be taken as a very good basis for convenient additions, in various ways. Thus, for instance, if either of the longer sides of the building faced the south it might be provided with a porch of substantial dimensions; or to obtain additional room a lean-to or L or T-extension could be built on the rear side.

The standard section-house plans of the Wabash R. R. (Fig. 356) show a feature that is highly commendable, but not commonly found with railway buildings of this class, and that is a cellar. The house is also well arranged in other respects, there being a pantry and stairway to the cellar convenient to the kitchen, and a chimney in every room in the building. For plans of a large number of tool houses and section houses the reader is referred to an extensively illustrated work on railroad structures entitled "Buildings and Structures of American Railroads," by Walter G. Berg, chief engineer of the Lehigh Valley R. R.

The Hand Cars of the Pike's Peak Cog Road (See Index).

CHAPTER X.

WORK TRAINS.

140.—There is much track work which can be done most profitably with a train and crew, and much that cannot well be done in any other way. For various kinds of work a train of some kind is needed, at least a portion of the time, or at one or more intervals during the year, on every road or division; and in some cases it can be kept employed constantly. But whether the need of a work train be for little or much of the time, sooner or later such exigencies will arise as will make the demand for the train practically imperative, on any road where the reliability of the train service is of consequence. Such preparation should be made, therefore, that whenever the demand comes everything will be in readiness as soon as the crew can be made up. Compared with the ordinary expense for railroad equipment, the necessary cost of such preparation is small and it is a profitable investment in the end.

141. The Train.—The kind of cars which make up a work train depends, of course, upon the work the train is handling at the time; and as the different kinds of work usually handled by work trains and their crews are taken up in separate sections, the cars needed in each case, as well as those which must be kept in readiness with their equipments, are discussed in those sections. There are always required a locomotive, a caboose for the crew and workmen, and a flat car provided with a large tool chest or two. A locomotive too much worn for regular train service but which can be profitably used for awhile before going to the shops, will answer. Too often, though, the engine furnished the work train is one so badly out of repair that much time is lost in getting over the road; and the work is seriously hindered if it is unable to pull good-sized loads. It should preferably be a passenger engine of fair weight, so that passenger-train time can be made; and the train should be so equipped that, if necessary, it will be able to run as second section of a passenger train. In this connection, all cars used in work-train service should be equipped with air brakes; and cars having flat wheels and old cars too weak to carry heavy loads at high speed should not be used. In some cases—on level roads, for instance—an old locomotive too light for the increased train loads of the road is fitted up and used exclusively in work-train service. On roads where the grades are not heavy such an engine usually does quite well, and if it is too light to be of service at wrecks, a heavier one can be sent out on such occasions, for it sometimes becomes necessary to send two or three. A tender having a large capacity for fuel and water will contribute much toward the efficiency of a locomotive for work-train service. It sometimes happens that, owing to the interference of traffic trains, a necessary run for water is the cause of losing several hours' work. A switch rope should always be carried on the tender.

The caboose should be large—at least 40 ft. long inside. The inside should not be cut up by partitions, but the space should be in one compartment, and open. The seats are best arranged along the sides—generally chests with hinged covers, in which can be stored fuel, dinner pails, coupling links, etc. The seats should be provided with cushions of some sort, and a few arm-chairs will be found articles of much comfort to tired workmen when the caboose is crowded, and should be furnished, as far as there is room. There should be a heavy, flat-top heating stove anchored to the floor, at one side, at the middle of the car, a writing desk in one corner and a tank for drinking water in another corner. The windows should be large, so as to give good ventilation in hot weather. The doors at the ends should be large, and the platforms should also be large, covered overhead, and there should be a hand-brake on each. The steps and grab-irons should be large and conveniently placed. There should be a cellar or store box hanging to the middle of the car, underneath, and in it should be carried a 3-in. manila switch rope about 80 ft. long and two snatch blocks; two journal jacks and two heavy screw jacks; two ⅞-in. chains, each 16 ft. long; two rerailing frogs and two dollies. There need be no seats or windows aloft, as is necessary for a freight caboose, but hand-irons for getting to the roof should be provided at each end.

The flat car used as a tool car should always be coupled with the caboose; preferably ahead of it. A 2x8-in. plank should be hung along each side of this car at the proper hight to serve as a step, so that men may get aboard quickly and easily. Along the outer edge of the car floor a 2x2-in. scantling should be spiked or bolted fast to serve as a grab-piece for men getting on the car. On this car there should be two large tool boxes for holding picks and shovels, but both picks and shovels should not be thrown into the same box. They should also contain a few pinch bars, spike hammers, a claw bar, gage, track wrench and a dozen pairs of rail tongs.

Of course, the train may run on or hold main track only subject to the orders of the train dispatcher. Before starting out, full information should be given the dispatcher regarding the character of the work to be done, the limits within which it is to be done, the probable time required for doing it and where it is desired that the train shall go after getting through at any place. With this understanding the dispatcher may be able to make better arrangements than would be possible if he knew nothing about the plans for the train. Wherever it can be done without deranging the service too much, the work train should be allowed to hold main track until the arrival of freight or second-class trains in sight (always protecting itself by flagging), since it is frequently the case that when such trains are late much more time might be used by the work train, whereas, it would otherwise be lost while standing in some siding waiting for the arrival of the belated train. The case of a heavy grade against the freight train could be cited as an instance where this rule might have to be modified. It is a good plan to carry a velocipede or speeder on the flat (tool) car, as it can often be used to good advantage when it becomes desirable to "flag in" to some point. Work trains running "special" should whistle before entering every curve, so as to give hand cars a chance.

142. The Crew.—The crew required to handle the train is an engineer, fireman, at least one brakeman, and a conductor. While the brakeman is out flagging, the fireman should assist by opening switches. The conductor is sometimes dispensed with and the foreman of the working force is given charge of the running of the train, but since there is always need for two men to act as brakemen, and as the conductor usually takes the place of one of them, it is better to have him. To require too many duties of the foreman may hinder him in overseeing the working crew.

The foreman of the working force should be an active, decisive, coolheaded, intelligent man who understands all kinds of track work and who has previously been a laborer on a work train himself. He should be a more capable man than is necessarily required for the average section foreman, and his executive ability should be such that he can, at times, get intelligent laborers to hurry a little without offending them. He should be well acquainted with the rules and principles governing the running of trains, so that he can, in consultation with the conductor, lay out his work to best advantage. The man holding this position ought to be, or at any rate ought to be capable of being, the assistant roadmaster. It seldom works well to have the conductor act as foreman of the working force: first, because trainmen do not ordinarily take interest in track work, even if they have had previous experience in it; and, secondly, a trainman who is held responsible for one duty, such as the safe running of a train, and who does it well, is not so apt to feel responsible in a like degree for some other duty not usually intrusted to trainmen. He is, therefore, inclined to look upon the oversight of the work as a secondary matter, and feel that any slight negligence of it is not going to be charged against his record as conductor. It is, therefore, better to have the man in charge of the work responsible directly to the track department and to that department only.

The working force should comprise at least 20 laborers, and as many more as can be profitably employed at the particular work to be done. The cost to a railway company for a locomotive and fuel, and crew to run it, is about $25 per day, or about the wages of 20 laborers. There is no economy in sending out a work train without enough help to accomplish something proportionate to the entire cost. If the train is kept constantly at work it has its own crew, of course, but if it is used only a few days at a time inexperienced men picked up temporarily will not always make a satisfactory showing, and the scheme of sending out a work train at occasional intervals is sometimes called in question. When, however, it is considered that a competent work-train crew may oftentimes dispose of much section work, and to vastly better advantage than is possible for the regular section crews, it will sometimes pay to draw upon the section help for manning the work train temporarily, if it cannot be done in any other way. Under such circumstances the practice of calling a man from each section is a good one. These men will understand the work better from the start and accomplish a great deal more than green men hired upon the street. An increase of 10 or 20 cents per day in wages will usually be an inducement for them to cheerfully leave the section temporarily, especially with single men who have to pay board. Oftentimes a crew has been made up in this way where the management would not have consented to the hiring of a special crew. An opportune time to do this, providing the work is also seasonable, is about the usual time of laying off section hands, in the fall. Men sent from the sections to work with a train should each take a shovel and be responsible for its return when the user returns. Another plan, where the work train is intended only for temporary service, is to organize the crew with one of the floating gangs as a nucleus. In selecting a work-train crew, young or middle-aged men only should be sought, because climbing on and off cars is too hard work for old men, and, besides, to them, it is dangerous.

It should be the aim of the work-train foreman to keep the men employed as constantly as possible, and by all means to avoid working over hours. The men should not fall into the habit of thinking that because the train must run to a siding to clear the main track the company can afford to pay them for standing idle. The men get abundant rest while riding to and fro on trips that are really necessary. Any work which the foreman can see about him, for which he has tools, he should set his men to doing. Thus, for example, he may find opportunity to clean station grounds, or in summer time he can often steal a march on some section foreman by striking in and grubbing a half mile or more of grass in the track, while waiting for his train; or the men might work at ditching or policing. A half hour's waiting with a gang of 20 men is the loss of a day's labor paid for by the company.

143. Boarding Accommodations.—A question of importance in some situations is whether or not the crew of a work train should be boarded with the train. Unless the headquarters for the train are near the middle of the division it will frequently happen on single-track roads that much time will be lost running to and from work, and the hours of all connected with the train are much prolonged. This is so not altogether on account of the distance, but because of interference from the traffic trains, especially when scheduled trains happen to be late. On roads with long divisions, principally in the West, it is usually found to be a matter of much convenience to the company, and of comparatively little cost, to furnish facilities for board and lodging for the men, so that after the day's work the train may lie over at the nearest telegraph station.

Lodging in bunk cars should be furnished the men free of charge, and board at cost. It is rank injustice and little short of robbery to let the boarding of a work-train crew to contractors, or to allow the foreman or anyone else to run it at a profit. The same sentiments apply to the practice of running a commissary car to pay off the workmen in overalls and tobacco, at high price. Wherever it may be found necessary to supply the workmen with ordinary necessities of living it should be the business of the company to see that these things are furnished at cost. It is quite generally known that work-train foremen on some roads are, or have been, permitted to "make a little on the side" by boarding the workmen on their own account, the company fixing the price of board and collecting the same from the men's wages, while the foreman furnishes the board and, of course, decides upon the quality thereof. Looked at from an income standpoint, some transactions of this kind would easily lead one to believe that the chief business of the foreman was the keeping of boarders, while his duties as an overseer of labor and the monthly compensation therefor was the real matter "on the side." The most satisfactory method of boarding a work-train crew is on the club plan, each man paying his share of the cost. The company can well afford to furnish a car for the purpose of cooking and also pay the cost of cooking. The cost of provisions should then be borne equally among the whole crew, both the train crew and working force, the foreman and the cook—all who eat. There is no good reason why the cook should not be paid satisfactory wages and then share in the boarding expense, the same as the rest. Under such an arrangement some cooks would have reason to be less wasteful of the supplies which pass through their hands.

The cost of equipping a kitchen car, outside of the cost of the car itself, is small. A large, clean box car, preferably a new one, at least 34 ft. long on the inside, may be selected and end doors and four side windows should be put in. A large cooking range, well secured to the floor, should be placed in or near one corner. This end of the car should be fitted with cupboard and side table, and a water tank or reservoir having a capacity of at least four or five barrels should be provided and so arranged that it may be filled by hose or at water tanks. The reservoir is sometimes placed underneath the floor, taking its supply by hose from a water car or from the locomotive tender. The supply for the kitchen can be had through a pump at the sink. For a small crew the kitchen and dining facilities may be combined in one car, in which case an eating table, oilcloth-covered, may extend two-thirds the length of the car. This table will accommodate about

24 men at one sitting. If the working crew exceeds this number dining-car facilities ought to be provided in a separate car or cars. For this purpose ordinary box cars with a table running the whole length of the car, except for room to walk around the end of the table at each end door of the car, will answer; if there is only one dining car it should preferably be coupled in at the stove end of the kitchen car. By taking the dining table out of the kitchen car, one end of the latter is then available as a storage room for provisions, etc., for a large crew. Old baggage or combination cars remodeled to suit the service are much used for work-train dining cars.

One cook can prepare food for 25 men; and if the kitchen and dining facilities are combined in one car, and the men not permitted to rush in prematurely at meal time, he can set the table for that many and do the waiting. For a larger crew, especially if the victuals have to be carried into an adjoining car, he will need assistance in the cooking or in waiting on the tables. The dishes, plates, etc., should be of tin, and the cooking utensils of large capacity. There should be a small cleat along the edges of the table to keep dishes from being jarred off while the car is running, or when it gets bumped. A large cellar should be suspended underneath the car and provided with locks, for storing meats, vegetables, etc., and an ice box might also be arranged in it. There should be provided a half dozen wash basins, to be used outside, a pipe leading from the tank inside the car serving as a convenient water supply. Unless basins, soap and towels are provided in a convenient manner there are always some men who will neglect washing at meal time, much to the discomfort of those of more cleanly habits.

A supply of provisions sufficient to last several days should be bought wholesale, each time, so that the board will cost a minimum. Daily supplies of fresh meat and other perishables, as per the foreman's order, can, with but little trouble to the company, be sent by the regular trains. The foreman should see to the accounting for the same and to the distribution of the charges. Everybody should be treated alike—second table with the first, if meals have to be served in that way—and the foreman should not permit the trainmen to slip into the kitchen at odd spells to feast on delicacies or to get their meals by special order. The regular meals should be good enough for all.

The following bill of supplies is supposed to be a fair estimate of the needs of 25 working men for 7 days, giving a good variety—perhaps better than many would choose:

Flour	50 lbs.	Baking powder	1½ lbs.	Ginger	¼ lb.
Bread	175 lbs.	Steak and roast	125 lbs.	Pepper	1 lb.
Coffee	22 lbs.	Boiling meat	50 lbs.	Salt	9 lbs.
Tea	1¾ lbs.	Ham	38 lbs.	Baking soda	1 lb.
Crackers	25 lbs.	Bacon	18 lbs.	Mustard	2 bot.
Granulated sugar	40 lbs.	Salt pork	7 lbs.	Catsup	½ doz. bot.
Condensed milk	8 cans	Codfish	10 lbs.	Pickles	1½ gals.
Lard	20 lbs.	Beans	25 lbs.	Canned salmon	½ doz.
Butter	27 lbs.	Rice	8 lbs.	Can'd corned beef	1 doz.
Eggs	18 doz.	Oatmeal	8 lbs.	Dried peaches	8 lbs.
Potatoes	300 lbs.	Corn meal	15 lbs.	Dried apples	8 lbs.
Turnips	½ bush.	Tomatoes	12 cans.	Dried apricots	8 lbs.
Onions	¾ bush.	Corn	12 cans.	Prunes	10 lbs.
Cabbage	40 lbs.	Peas	6 cans.	Pie fruit	3½ gals.
Cheese	25 lbs.	Raisins	4 lbs.	Syrup	2 gals.
Vinegar	1 gal.	Nutmegs	1 doz.	Kerosene oil	2 gals.
Soap	20 cakes.	Cinnamon	1 pkg.		

Bread, of course, would not be furnished a week ahead, neither would fresh meat, in summer time. A half barrel (98 lbs.) of flour will make

175 lbs. or 175 loaves of bread. As pointed out in the chapter on track-laying, the baking for a large crew can be done by an extra cook working at night. Altogether, there is more meat in this bill than will be eaten by the number of men stated, but eggs, preserved and canned meats and fish will keep; and about this quantity should be on hand to fall back upon in case the regular supply of fresh meat should for any reason be delayed, as often happens. When fresh milk can be obtained it should be used in place of the condensed article, and 7 or 8 quarts per day will be required. In place of the dried fruits there might be substituted, in whole or in part, about 32 quarts of canned fruits. There are a few things included, such, for instance, as the cheese, onions, catsup, etc., which could be dispensed with, of course, and not materially affect the necessary supply. In summer time it is desirable to have ice, and an ice chest should be provided. A supply of 100 to 150 lbs. of ice on alternate days is sufficient for the kitchen purposes. The cooking should be regulated somewhat to the season and to the climate. For instance, during the hot months of summer or in a hot and dry desert country salt meats should be used sparingly, or only for the evening and Sunday meals; otherwise the men will be thirsty much of the time and drink too much water, causing them to become weak and incapacitated for work. In districts where the water is poor such food should be avoided as much as possible at all times.

When the work comes to an end the cook should clean the car thoroughly and put things in order. A few of such eatables as are not quickly perishable should be kept on hand, to be had in readiness in case this car should be needed at a wreck, a slide or in other emergency.

An ordinary box car fitted with a small stove and bunks serves well for sleeping quarters. While it is possible to arrange double berths in two rows the length of the car, so that a 34-ft. car can accommodate 40 men, in 20 berths (upper and lower) such an allotment of space is too close for comfort, as it does not give the men room enough outside the beds to sit or stand around. It is better to arrange eight double berths on one side and eight single berths on the other side, including upper and lower in each case, thus providing for 24 men, leaving a wider passageway between the berths and a large clear space between the two side doors. The latter space is necessary for stove room or for proper ventilation in hot weather; and it also permits access to the car from either side, the need for which alternates from one side to the other as the car is placed on different side-tracks, or to meet other conditions. There should be a side lamp attached to each side of the car (as in cabooses) on diagonally opposite sides of the large doors, some benches, and perhaps a small table. The fewer conveniences there are, the farther will the men straggle off nights and Sundays to find them in neighboring towns. For bedding the men usually furnish their own blankets, which, with some straw, are sufficient. The bunk car, if used permanently for such, should have four windows in the two sides, and there should be end doors, so that one may walk from car to car through the train while it is in motion. These changes cost but little and do not so alter the cars that they cannot readily be turned again to their former use. Old passenger coaches with the seats removed and fitted with berths are much used for work train sleeping cars. The caboose provides the train crew and foreman with desk room for necessary writing. The bunk and dining cars should be left on side-track near the work, for they need not necessarily be pulled about continually. A car-load of coal should be taken along, and a night watchman for the locomotive.

For large work-train crews employed with more or less regularity, specially designed double-deck boarding cars are used a good deal. The outfit of this style for the St. Paul & Duluth branch of the Northern Pacific Ry. consists of two cars with accommodations for about 60 men. Each car is 40 ft. 8 ins. long, 10 ft. wide, and 16 ft. 3 ins. high, from top of rail to running board. The head room at all points on the road is sufficient to admit the passage of a car of this size. One of the cars in each outfit is known as the kitchen car, the lower floor being equipped with a range, ice chest, hot-water tanks and other necessary appliances. Over the cooking range there is a large hood to carry the heat and steam up through the second story, and there is a removable extension pipe above the roof to improve the draft. One end of the lower floor in this car is partitioned off for a foreman's office and dining room, which is used also by the train crew. The upper story has sleeping quarters for the foreman, train crew, and the cook and his helpers, and the remainder of the space is used for storage purposes. In the other car the entire space on the lower floor is used for a dining room. Instead of the usual arrangement of a long table extending lengthwise the car, there are a number of short tables placed crosswise the car, the length being such as to leave a clear passageway along one side, for the waiters. The dining room will seat 56 men at one time. The tables and benches are movable, so that the space may be

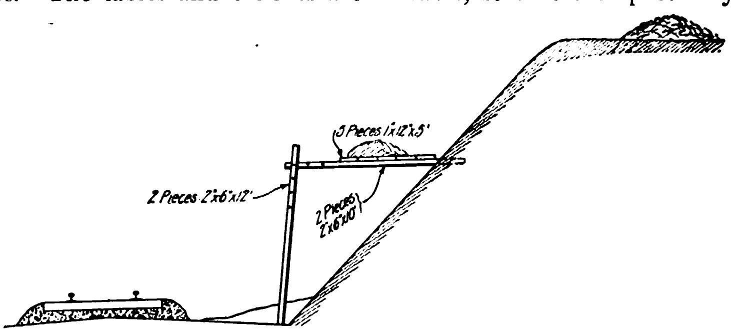


Fig. 357.—The Fort Ditching Scaffold, Southern Ry.

cleared to afford lounging room for the men at night and during stormy weather. The upper floor on this car is used entirely as sleeping quarters, and accommodations are provided for 48 men. The berths are double, upper and lower, with an aisle along the middle of the car. The car is well ventilated, there being a half window at the side of each berth. The upper story is entered by a stairway at each end of the car, but for emergency, as in case of fire, there are end doors convenient to the fixed ladders up the ends of the car. Owing to the unusual hight and large amount of surface presented to the wind, means are provided for attaching guy lines to the top corners of the car, to secure the car against uncomfortable swaying or danger of overturning when hard winds are blowing.

144. Ditching with the Train.—The task of cleaning out ditches in long, deep through cuts cannot be performed economically by the slow process of running the dirt or mud out on push cars; such is proper employment for the work train. Where the cuts are bad, ditches should be given a general cleaning out twice a year—in the spring, and again during the fall, before winter or the rainy season sets in. One advantage in handling the work with a train is that the material taken out of the ditches may then be used on fills which have shrunk away; and especially is such disposition of the material profitable if there be shrunken fills at the ends of bridges. Another advantage is that the means of transportation is of sufficient capacity to move large quantities of material, as when widening a cut that is too narrow. On many roads a sufficient quantity of material is taken from the ditches to maintain the fills to their proper width, and that such a balance may be maintained it is only necessary that some means of transporting the material be available. It frequently happens, also, that such material can be disposed of to good advantage in filling for a side-track about to be put in, or for a change of alignment somewhere in the main line, or to fill in trestle bridges. It is far better to dispose of the material in such ways, even if it must be carried some distance, than to run to a near-by siding to unload where the material is not needed, purely with the idea of utilizing time while waiting for trains to pass. On roads running through a hilly or uneven country it is usual to find fills on every section, where spare material may be deposited to good purpose.

The work of ditching should be thorough. Loose material should be cleaned from the faces of the cuts, and this can usually be scraped down while the work train is running to clear for the traffic trains. In summer time when the ground is dry and hard the picks may have to be used a good deal; hence a good supply of them should be carried along, so that a sufficient number may always be kept sharp. The most convenient way to carry picks while in use is to stick the handles downward through the stake pockets and let them hang at the side of the car. They are handy to get from this position, secure while the train is moving, and out of the way while unloading. If thrown upon the car they might get covered with material or be jarred off while the train is running. In some situations, as, for instance, where there is a good deal of ditching to be done in one place, particularly if the ground is wet, it is cheaper to use a plow than picks.

Flat cars used for moving dirt or gravel should have smooth floors. In unloading from cars which have floors cut up or so rough that there is not a good bottom for the shovel, much time is lost. Before loading the cars all spikes which may be projecting above the floor planks should be driven down. When loading material on cars during freezing weather, as must sometimes be done at slides or on other occasions, the material may be kept from freezing to the car, for several hours, by sprinkling the car floor with brine, or by scattering salt over it, just before loading. A water barrel and garden sprinkler furnish all the necessary equipment.

It frequently happens that in ditching cuts with work trains there are long delays waiting at sidings for the traffic trains to pass, and under ordinary methods of working it is not always possible to keep the men employed to advantage. Where the ground is firm it is permissible to deposit moderate quantities of ditch material on top of the banks, providing it is thrown well back from the top of the slope and does not interfere with the surface ditches. Wherever the material may be disposed of in this manner while the train is away, the ditching of the cut can be carried on without interruption. For getting material out of cuts that are too deep for casting at a single throw, Resident Engineer W. A. Fort, of the Southern Ry., has used a scaffold, of which he is the designer. As illustrated in Fig. 357, it consists of two 2x6-in. posts 12 ft. long, with two 2x6-in. horizontal pieces 10 ft. long running into the bank to support a platform of five 1x12-in. boards 5 ft. long, upon which material from the ditches is thrown in process of casting it out of the cut by stages. The posts and horizontal supports are bored at intervals to permit adjustment of the hight of the platform, and in a deep cut one scaffold may be placed above another. The device is obviously simple, and is readily carried about on a push car or work train. This scaffold was first furnished the section foremen, and was found to be of such value as a time saver when trains were late and the foreman was not allowed to use a flag to protect a push car, that the ditching trains were equipped with them. By placing one man on the scaffold and two in the ditch the dirt can be kept moving regardless of trains.

Ditching Machines.—Ordinary ditching is usually done by hand, but on some roads running through long stretches of swampy land or mellow soil machinery is brought into use. The Barnhart railroad ditcher consists of a light excavator or steam shovel mounted upon a timber frame, which is dragged along between the side stakes of ordinary flat cars in the same manner that an unloading plow is moved. The excavator rests directly upon a turntable which can be operated throughout a complete circle, and the handle of the dipper is long enough to permit the machine to excavate to the required depth below the track. The machine is supplied with a winding drum and wire rope tackle, which is stretched out over the cars ahead of the machine and anchored, thus enabling the machine to drag itself over the cars and travel away from the material which it excavates and loads upon the car behind. The radius of the boom is such that excavation can be made sufficiently wide to prepare the roadbed for a second track. This machine has been used on the Baltimore & Ohio, the Pittsburg & Western, the South Carolina and other southern railways.

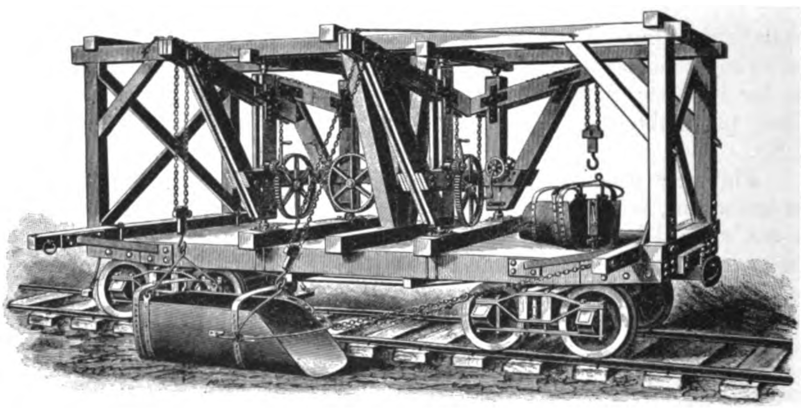


Fig. 358.—American Railway Ditching Car.

Another method of ditching by machinery is by the use of a car provided with side attachments which plow or scoop up the material by the movement of the car when coupled in with a work train or directly to a locomotive. The "American" railway ditching machine (Fig. 358) consists of a flat car upon which is constructed a heavy framework, strongly braced and provided with two cranes on either side. A car with low wheels, 20 ins. in diameter, is considered the best, although ordinary flat cars with 33-in. wheels will do the work. The ditching operations are performed by dragging a heavy scoop, of about 1½ cu. yds. capacity, at the side of the car. The scoop has 3 bails: one lifting vertically at the rear, another lifting vertically at the front end and another pulling horizontally at the front end, to which is attached a chain made fast to a projecting cross beam at one end of the car, for hauling the scoop. The scoop is suspended from the two cranes by means of chains attached to the vertical bails and wound up by winches on the car, so that the inclination of the scoop and the depth of scooping are regulated by the winches. The setting of the crane regulates the distance of the ditch from the track. By attaching a scoop to either side of the car, ditching operations may be carried on at both sides of the track simultaneously. The attachments are easily reversible, and can be worked either way without turning the car. In service the machine is roofed over, so as to enable the men to use it in stormy weather, at which time the condition of the ground is most favorable to the operation of the machine. The machine works best in muddy or wet earth, but can be used with good effect in dry earth which has been plowed. The material scooped up is held until the train is run to a fill or other point for dumping. The scoop is dumped by winding up on the winch which lifts the rear end. This type of machine has been used on the Minneapolis, St. Paul & Sault Ste. Marie, the Chicago, Milwaukee & St. Paul and other roads in the Northwest. A machine of simpler construction which has been used on the Chicago, Ft. Madison & Des Moines R. R., has a 12x12-in. beam 20 ft. long extending crosswise the car and supported upon braced posts, with winches for raising or lowering the scoops, which are suspended by ropes passing over pulleys at the extremities of the beam.

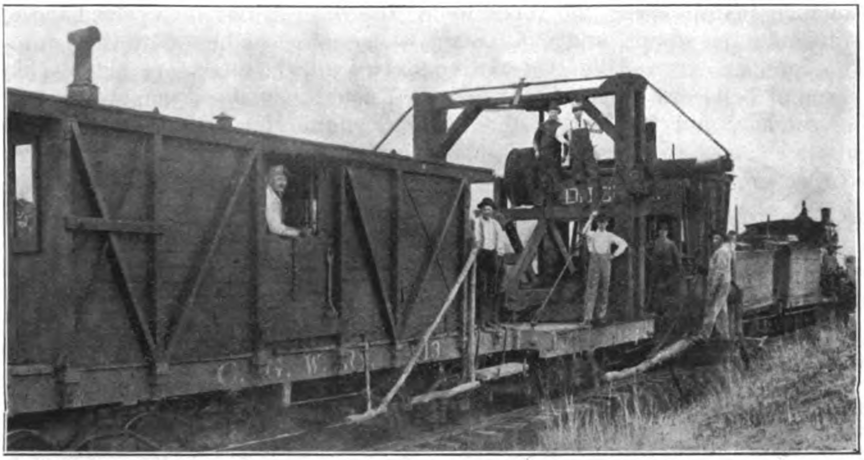


Fig. 359.—Ditching Train, Chicago Great Western Ry.

The Chicago, Great Western and the Kansas City Southern roads. have ditching cars with machinery operated by steam. In each case the working apparatus consists of a flat car with a housing at the forward end covering a boiler and engine which furnish the hoisting power; a hoisting shaft, with chains, mounted upon a strong frame which rests upon a turntable; and a scoop suspended from the hoisting shaft at either side of the car. The hoisting shaft projects past its supporting frame at either side, being of sufficient length to drop the scoop into the ditch at the desired distance from the track. When the car is in service the frame is revolved to stand crosswise the car (Fig. 359) and is held firmly in place by stay rods passing from the car decking to the top part of the frame. When out of service it is necessary to revolve the frame 90 deg., or to a position parallel with the car (Fig. 360), in order to clear for transit. The turntable upon which the frame rests is operated by the hoisting engine. The scoops of the Chicago Great Western ditcher are made of boiler plate and, on the average, each will hold a load of 1¾ cu. yds., the capacity depending somewhat upon the character of the material. The front or cutting edge of the bottom is reinforced with three teeth, after the manner of a steam-shovel dipper. The scoop is provided with a strong bail, and at the back side or closed end there is a strong socket into which is fitted a pole about 10 ft. long and 6 ins. in diameter. This pole serves as a means of tipping the scoop while it is taking its load, and is controlled by a rope attached to the end of the pole and passed through a pulley block suspended from the hoisting shaft. The scoop is hauled in the ditch by two chains, one attached to either side, to keep it straight with the ditch. The chains are attached to a stout cross beam which rests upon hangers suspended from the sills of the car. When the scoops are put into use this beam is pulled out to project over the ditch and is held by a stay rod attached to the front corner of the car.

The ditching train consists ,of a locomotive, followed by an extra tender, which serves the steam plant of the ditching car; behind the extra tender the ditching car is coupled in, and in rear of the ditching car there is a "tool car." All the cars are air-braked, and the tool car is provided with a conductor's valve for quick application. The tool car carries, besides other tools, a forge and blacksmithing outfit, for repairing chains, clevises, etc. The operating force (when working both sides) consists of six men, including a hoisting engineer, who does his own firing; two men manipulating the ropes to fill the scoops; two men who handle and dump the scoops, and a foreman, who is also conductor of the train. The foreman sits in the tool car and gives all the necessary signals by means of bell cords, there being one cord running to the locomotive, over the ditcher, and another to the hoisting engine for signaling when to raise and lower the scoops. Besides the ditching crew there are two flagmen, to protect the train.

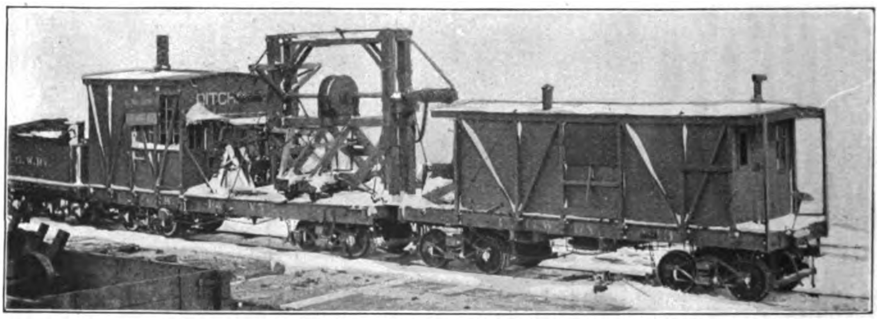


Fig. 360.—Chicago Great Western Ditcher Arranged for Transit.

The manipulation of the train and ditching apparatus is about as follows: As the train arrives at the ditch the scoops are quickly lowered, and as the train starts forward each scoop is tilted by the pole and rope arrangement, and as soon as it receives its load a man jumps down and sets a dog, which extends from the back side of the scoop to the middle of the bail and prevents the scoop from tilting and dropping its load. The scoop is then immediately hoisted and the train starts for the dump. On the way, while the train is in motion, the scoop is drawn up and the rear end is hitched to the loose end of the hoisting chain, which hangs from the shaft, being made fast to the spool of the winding shaft at about the middle (of the chain); and the two parts of the chain are wrapped several times around the spool, in opposite directions, so that the turning of the shaft unwinds one part of the chain while it winds up the other. As the dumping ground is reached the shaft is revolved as though to lower the scoop, thus unwinding the chain attached to the bail and winding up on the chain attached to the rear of the scoop. The scoop being thus hung up on its rear end, dumps itself. Meantime the train is quickly stopped and immediately starts back to the ditch, being kept continually in motion except when reversing direction and when stopping an instant for the men to set the dogs on the scoops. The train may run either way to dump, and, when ditching only one side, the off scoop is filled with stone. In usual practice the pulling beam and hoisting chains are set to excavate the ditches 14 ft. 8 ins. from inside to inside. The car is also used to slope down the bank where the material is dumped, there being for this purpose a moldboard connected with the pulling beam and maintained in upright position by brace pieces footing into shoes which slide on the ground, and by brace struts abutting against the car. When it is desired to pull dirt toward the track the sloper is held to its work by block and tackle attached to the car.

An average day's work with the machine, when within convenient distance of the dumping place, is 300 cu. yds. of material moved. Of course a great deal depends upon the amount of time lost from interference with the traffic trains. At one time while working on Sunday the ditching train made 91 trips, with 4 cu. yds. of material at each trip, the distance covered in a round trip being 700 ft. more than a mile. On this day the ditching train had to run to clear for six stock trains. On another occasion 656 cu. yds. of material was taken out in seven hours. For a number of years the machine was used from early spring to late in the fall.

Fig. 362.—Dumping the Scoops.

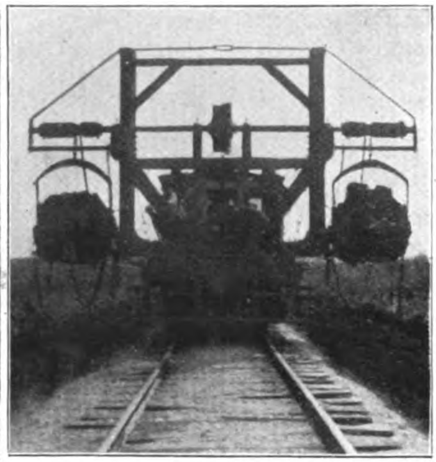


Fig. 361.—Loaded Scoops in Transit.

The ditching car of the Kansas City Southern Ry. is quite similar to the Chicago Great Western machine, on general lines, but essentially different in a number of the details of operation. The ditching machine and all the appurtenances necessary to its operation are carried on a single car, the hoisting engine taking steam from the locomotive. The hauling beam on each side is hinged, and when put into service is swung out at right angles and secured by a stay rod. As may be seen in Figs. 361 and 362, this ditcher has a small shaft below the main hoisting shaft, to which is attached a chain for the purpose of raising the inner side of the scoop, to give the ditch the proper slope for drainage. This lower shaft does not revolve, the tilting of the scoop being adjusted by lengthening or shortening the chain. While taking its load the scoop is steered and maintained in balance by means of a guiding pole 13½ ft. long. The scoop, which is 6 ft. long, 4½ ft. wide and 3 ft. deep, is hauled by two chains attached to its sides, at its front end, and to the pulling beam. The capacity of each scoop is 3 to 3½ cu. yds., and each reaches 14 ft. from the center of the track, or a distance of 28 ft. over all, for the machine.

The pulling beam is hinged to a side post at a point higher than the decking of the car, thus making it possible to swing the beam onto the car when it is not in use and save considerable time which would otherwise be occupied in lifting it and putting it in place.

This machine is used in cuttings where the amount of material is too small to be excavated at economical cost by a steam shovel. If the ground is hard it is first loosened up by hitching a heavy plow to the pulling beam and plowing several furrows through the cut. In excavating the material the scoops are hauled forward until filled and are then hoisted high enough to clear objects at the side of the track, and maintained in horizontal position, as shown in Fig. 361. The locomotive then runs to some near-by embankment or other point where filling material is in demand. The scoop is dumped by hooking to its rear end a chain wound upon the hoisting shaft in the reverse direction from that in which the chain is wound which supports the bail. When it is desired to dump the load the hoisting shaft is revolved to unwind the latter and wind up the former, thus tilting up the scoop and dumping the load, as shown in Fig. 362.

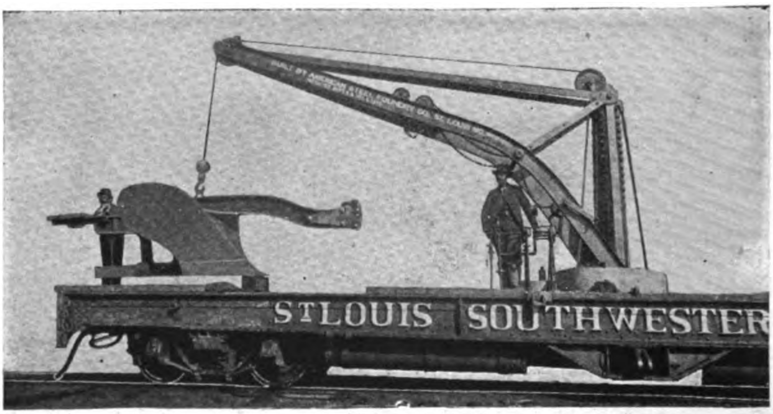


Fig. 363.—Doddridge Ditching Car.

The average amount of dirt handled with this machine during one season's work was a little more than 400 cu. yds. per day, carried an average distance of 1800 ft. This included material taken out of cuts containing rocks, stumps, etc., and from other places where considerable time was lost in removing obstacles that could not be handled by the scoop. At times as high as 900 cu. yds. of material was handled in one day. The cost of handling the dirt has ranged from 7.74 to 9 cents per cu. yd. This includes the cost of labor, train crew, use of locomotive, fuel, repairs to ditcher, and, in fact, all costs. The limit of economical haul, as determined from the experience with the machine on this road, was found to be about 4000 ft. The car and machinery were designed by Mr. F. Mertscheimer, superintendent of motive power. The plan drawings and dimensions in detail were published in the Railway and Engineering Review of Jan. 12, 1901.

The Doddridge ditching car, designed by Mr. W. B. Doddridge, while general manager of the Missouri Pacific Ry., and used quite extensively on the St. Louis Southwestern, the Texas Midland and the Minneapolis & St. Louis and other roads, is worked by compressed air supplied by the air brake system. The car itself is 50 ft. long and, with the exception of the decking, is constructed entirely of steel or iron. Both side and center sills are plate girders 18 ins. deep, strongly braced. The car has attachments for handling material in excavating ditches, building up and re-enforcing embankments, lowering track, raising track, altering grades and filling. All of these implements or tools are carried on the car and are composed of a plow, scraper, scoop and shoulder former. At the center of the car (Fig. 363) there is mounted a revolving crane 9 ft. high, having a reach of 14 ft. from the center of the car, capable of raising a load of 8000 lbs., and swinging through an entire circle. The crane is provided with two cylinders: one 12 ins. in diameter and 14 ft. 7 ins. stroke, for hoisting; and another 12 ins. in diameter and 9 ft. 5 ins. length of stroke, for swinging the crane. In addition to the crane cylinders there are four air cylinders near the four corners of the car, each 8 ins. in diameter and 5 ft. 4½ ins. long, for operating the plow guides. The air supply is stored in five cylindrical reservoirs, each 22 ins. in diameter and 10 ft. long, secured to the frame beneath the floor of the car.

In operation, the plow is generally used first. This is of cast steel, in one piece, except the moldboard, which is of heavy boiler plate, and weighs 2500 lbs. The plow is swung from its position on the car by the crane and is held to its work by four attachments. There is a draft cable attached to a heavy steel casting forming the end sill of the car, which has extensions at both sides of the car for this purpose. The depth at which the plow runs is regulated by the crane hoisting cable, and the plow is held at the desired distance from the car by a tubular strut attached to the front end of the beam, as shown in Fig. 364. The plow is maintained in a vertical position by a strut attached to the rear or upwardly deflecting extension of the beam, the strut being operated by the piston rod of an air cylinder. At the rear end of the beam of the plow there is a small platform upon which a rider may stand while the plow is in operation. The plow cuts a furrow 24 ins. wide and 30 ins. deep, if such depth is desired. It can be run as far out as 20 ft. from the center of the track and at an elevation of 10 ft. above to 16 ft. below the top of

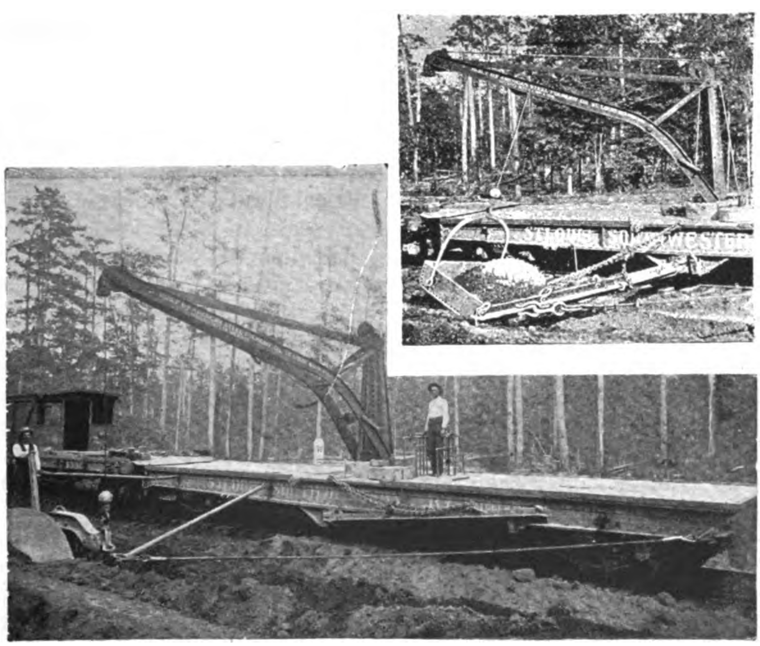


Fig. 364.—Doddridge Ditching Car, Plowing and Scraping.

rail. The tool next used after the ground has been furrowed up by the plow depends upon the character of the work to be accomplished. If it is desired to level down a strip of earth next the track the scraper is used; or if the embankment needs strengthening the scraper is used, being so attached as to carry the earth toward the track. The shoulder former is then hauled along to even off the surface of the roadway to a uniform contour. In ditching operations the scoop is used.

The scraper consists of a heavy moldboard, such as is used in ordinary road machines, and is braced at the back to horizontal trailing pieces which maintain it in a vertical position. It is attached to the end sill extension of the car by a draft cable and maintained at proper distance from the car by the swing beam or tubular distance bar. The nose or forward end of the scraper is attached to the swing beam by a short piece of chain and the amount of dirt scraped is controlled by the hoisting cable attached to the rear end of the scraper, which gives it the inclination. The scraper will bring material toward the track from a distance of 20 ft. from the center of the track, and will throw material either to or from the track, as may be desired. The shoulder former consists of a heavy scraper having a bottom edge shaped to the desired cross section and, as previously explained, is used for leveling material brought up by the scraper or dumped at the side of the track. It is attached to the side of the car by a pivot hinge, at one end, and to a draft cable at the other. It is re-enforced at the rear by several tubular struts bearing against the side of the car. The depth at which it works is regulated by the hoisting cable, attached to it at the top, at the middle of its length.

The operation of scooping is shown in Fig. 364. The scoop is 4 ft. wide, 8 ft. long and has a capacity of 3½ cu. yds. It is maintained at proper distance from the car by the swing beam, and the depth of ditch is regulated by the hoisting cable, which also is the means by which the scoop is dumped. It is hauled by a draft cable attached to the end sill extension of the car. It can be used at any point from the ends of the ties to 20 ft. from the center of the track. It comes into use in ditching or when, after plowing a cut, more material is turned up than is required to form the shoulder. The dirt taken up is carried to the end of the cut or to a fill, to be deposited. It is easily seen how the use of this tool could be readily adapted to the excavation of the summits of grades in lowering track.

All of the operations of this car are manipulated at a single point on the car by one operator, by means of cocks in pipe connection with the various cylinders of the car. The machinery is worked by one man who handles the air and two laborers who attend to the shifting and adjusting of the side attachments. When not in use as a track tool the car is stationed at a division point, and in emergencies is utilized as a wrecker, for which purpose it is readily adaptable, being quickly gotten into action simply by coupling on a locomotive to get the air connection. In wrecks where the lifting is not too heavy the car does rapid work. So extensive and effective have been the operations of this car in the swamp lands of Arkansas that farms and forests in some cases have been drained many miles back from the railroad.

145. Distributing Ties.—The details of the work of distributing ties for renewals vary considerably with different roads, according to conditions of supply, density of the regular traffic, ideas concerning economical methods, etc. Where the supply of ties can be bought in the district tributary to the road they are usually received at the stations or at side-tracks and loaded upon flat cars, to be distributed by the section men or by a work-train crew. If the ties are received at numerous points more or less uniformly located part of the crew can be employed at loading while the remainder are distributing. If, however, the ties have to be loaded some distance from the points where they are to be used it is a good plan to load a long train of cars at one time and side-track them at points convenient for the work of distribution. This arrangement saves much running to and fro over the road, for as fast as the ties are unloaded the empty cars can be set out and loaded cars picked up without running considerable distance. A similar method is to have the ties shipped to the stations and side-tracks in order, beginning at the end of the division nearest to the point of shipment and setting the cars out in lots according to the number of ties needed, and then begin the distribution with a work train and keep it steadily employed until all the ties are laid down. The distributing crew is sometimes an extra gang or work-train crew and sometimes it is made up of two or three section crews.

For rapid distribution the ties should be loaded on flat cars, crosswise the car, except two under courses at each end. These courses should be placed lengthwise the car, each course blocked under the outer end by a tie placed crosswise, so as to give it a pitch inward. These slanting courses act as guards to keep the ties placed crosswise from being jarred or rolled over the end of the car. If in these slanting courses the two thickest ties of each course are placed on the outside, they will be held in place by the weight from above and no stakes will be needed. Enough room should be reserved at the end of the car for the brake to be used. On some roads flat cars for use in distributing ties are specially fitted up with permanent end boards. Ties received from points beyond the particular line of railway are usually shipped in box or stock cars, and, if received at about the time they are required for distribution, are usually unloaded from these cars direct to the side of the roadbed. In long-distance shipments of ties over a single line of railway or system, it is also quite common practice to use box, stock, or gondola cars with high sides; this for two principal reasons: In the first place, the commercial shipments in cars of the kind named may be heavier in one direction than in the other, and to avoid hauling some of these cars back empty they are loaded with company material. Again, accidents have happened by ties working out on flat cars and striking switch stands, through truss bridges, the sides of tunnels and snow sheds; and even cars and engines standing on side-track or passing on another track have been struck by ties that stuck out from piles on flat cars.

The exact number of ties wanted for renewals in places can be known and the right number of new ties can be dropped off, just as well as not. Much useless handling and trucking of ties results from throwing them off by guess while distributing, for without some system of estimating or counting the number required and the number delivered there will usually be either too many or else not enough. Where ties are thrown off in excess of the requirements it is usually the case that many old ties which could profitably remain another year will be removed, simply to make room for all of the new ties. Some foremen seem to have the idea that new ties are necessarily the best medicine for rough track. On the other hand, if an insufficient number of ties are distributed in places, the deficiency must be made good by trucking, or else some old ties will remain in the track which ought to come out. The work of distributing ties should be conducted with such system that the required number may be had at all points. It will then not be necessary to redistribute the ties with a push car, and there can be no waste of timber. Just before the time for distributing comes, each foreman should carefully inspect the ties on his section and count the number needed for renewals between each two telegraph poles. This number should be marked with chalk on the pole which stands in the direction from which the train will come when distributing. The best plan is to take a short ladder and place the marking out of reach of mischievous persons. Then when the work train comes along it will be an easy matter to throw off the required number, almost in place. Another method that is sometimes followed is to drive a stake on the shoulder temporarily for each ten ties required.

When ties are delivered in box, stock or gondola cars a strong force is needed to unload them promptly—say 25 or 30 men. On the average it takes four men about 30 minutes to unload a box car holding 300 oak ties. If the ties are loaded on flat cars a few men can tumble them off rapidly, and 15 to 18 men are a sufficient force. The best way to control the number of ties put off when unloading from flat cars is to work the men in relays of a few men each. It is much easier to control the movements of a few men working rapidly than of a whole crew working at the ordinary gait. When unloading from flat cars four or five men besides one to tally are usually a sufficient force working at one time to do the unloading. The crew being small, the man keeping tally can easily stop the delivery of the ties from the cars as soon as the required number for the place has been thrown off, or by calling to individuals he can easily increase the number thrown off by a tie or two, if need be, after the signal has been given to stop unloading. Another way to stop the unloading as soon as the required number has been thrown off in a place is to designate each man in the gang by a number, and have it understood that each man whose number does not exceed the one sung out by the tally man is to throw off a tie. Suppose, for instance, there are 15 men in the gang and it is desired to unload 12 ties between two certain telegraph poles. The tally man would sing out "twelve," and each man up to and including No. 12 would throw off a tie. If, say, 22 ties were needed the tally man would cry out: "Once around and seven more," when every man in the gang would throw off a tie, and each man up to and including No. 7, one additional.

The train should not be run faster than 6 miles per hour; and on high fills quite slow, because in such places ties thrown too hard will roll to the bottom of the slope. The foreman of the section whereon the ties are being unloaded should invariably accompany the train to advise as to the number of ties wanted and the exact location of the same. It is also well to have the section crew, or part of it, follow the train on a hand car, to throw out any ties which may have fallen too close to the track. At narrow cuts it is a good plan to throw off the whole number in piles at each end of the cut, especially if the old ties are not to be taken out for some time, and the same is true for high, narrow embankments. Proper attention should be given to loading and throwing off the hardest ties for the curves, as heretofore pointed out. In distributing ties on curves observation should be taken of the side of the track from which the ties will have to be pulled in when making renewals, and the ties should be thrown off on that side, if there is room. Thus, for instance, it will frequently be found that in renewing ties on curves the ties must be pulled in from the outside of the curve.

The question of using way freight trains for tie distribution depends upon the traffic conditions. On roads where the local freight business is light it is found to be economical to send the ties out a few car-loads at a time with these trains, to be unloaded in place by the section men, who are previously notified to be on hand at the point where the ties are wanted. The delay to the train in waiting for the ties to be unloaded is necessarily considerable, and on roads where the local freight work is heavy the way trains are frequently or nearly always behind time, and the extra work of tie distribution is considered inexpedient. Such is also quite liable to be the decision where the ties are to be unloaded from box cars, or where a train-load of ties arrives and there is a demand for prompt release of the cars. Quite frequently part of the ties are distributed from way freight trains and part from work trains, on the same road. One situation under which such is the practice is where some of the ties are delivered at stations or sidings, the cars being set in for the section men to load, and afterward taken out by local freight to be unloaded by the same forces; ties delivered from outlying points, however, are handled by work train with a special gang. Where only one car-load or a few scattering car-loads are to be sent out it is convenient, of course, to use the local freight trains, in any case. Good authorities are occasionally quoted on both sides of this question, one view being that distribution from local freight trains is the cheapest way to handle ties, while, on the contrary, the experience of some other man is that the same method is expensive and unsatisfactory. The varying conditions of traffic above noted undoubtedly account for the difference. Mr. J. C. Rockhold, roadmaster with the San Francisco & San Joaquin Valley Ry. (Santa Fe system), has kindly favored me with a clear and comprehensive statement of practice under certain conditions which are quite extensively found. This statement, which covers a method of distribution not hitherto described, is published as § 200, Supplementary Notes.

As a general thing ties distributed from a work train are put off in better shape than from a way freight. The crews of the latter class of train, especially when late, are frequently inclined to rush the work too fast, either by urging the men or by moving the train too fast for the men to properly unload the ties. An ordinary result of such haste is that ties are thrown down embankments, into bridge openings, or are so sparsely distributed that much time is lost in carrying them to place when renewals are made. In distributing ties with a work train time is sometimes needlessly lost or wasted in attempting to do the work continuously. For purpose of illustration, suppose the train is proceeding from north to south and at a certain time must quit work and run six miles south to clear for a regular train. If another train is due at the point where the work stopped, in less than an hour, it is more advantageous to work back north from the passing siding after the first train has departed than to run back the six miles purposely to make the distribution continuous, for in the latter case the train will have but a few minutes to work before it must again run to clear, whereas if it starts in to work back from the siding the time otherwise consumed in running to and fro is employed in throwing off ties, and the gap can be closed up during some more favorable interval in the train schedule. For this reason it is usually more advantageous to select the passing points in the direction in which the work is progressing.

The best time to distribute ties is in the early spring, just before the time for renewing begins, and the counting of the old ties to be taken out should not be done until a few days before the new ones are distributed. Of course, on many roads it is necessary for the purchasing agent to have in the fall an estimate of the number of ties required the next spring for renewals, but an actual count in the fall comes so close upon the renewals made in the summer (when all unserviceable ties are supposed to have been removed) that it is but little if any better than a guess, because the probable condition of the ties six to eight months later is, after all, largely conjectural—the number counted may overrun or fall short of actual requirements the next spring; and it is an expensive mistake to distribute more ties than are actually needed. On old roads an estimate based upon the average renewals for a series of years is more rational than an actual count of the ties in the fall, and is sufficiently close for the purchasing agent. If a few ties are left over as the result of a liberal allowance on the general yearly average they will be all the better for the seasoning they get. Authorities on timber say that ties should be allowed to season at least a year before being put into the ground, but generally they are purchased green in the winter, distributed in the spring and put into the track in the spring and summer. There should, therefore, be no money lost if a few ties remain over for another year.

On roads where ties are handled by way freight it is quite customary to begin the distribution as early as January; this for the obvious reason that only a few car-loads can be distributed each day, and it is necessary to take a good deal of time in order to get over the division by spring. Again, on roads where ties are received from outlying sources of supply it is frequently the case that the distribution begins late in the fall, so as to release the cars promptly and avoid piling the ties up in the yards. It is doubtful whether anything is gained in either case. In the first place, ties should not be unloaded and left lying on the ground through the winter, as in this position they gather moisture from the ground, are covered with snow or lie in ditches or wet places and become water-soaked, so that the germs of decay are well induced before the tie sees any service at all. In order to obtain all the advantage possible from seasoning, the ties that are received during fall and winter should be carefully piled at points exposed to the winds and sun, but it costs no more to do this in the yards and along side-tracks and to load them up again on flat cars in the spring and deliver them right where they are wanted, than it does to pile them up all along the right of way and then carry them or truck them to place when the renewals are made. In the second place, the practice of piling up new ties along the right of way, to remain three to six months before they are used, is contrary to the principles of good policing. If the right of way is piled with new ties all winter and spring and with old ties all summer and perhaps most of the fall, there are but few months when it presents a clean or finished appearance. In the third place, as already explained, an accurate count of the ties to be renewed cannot be made until the time for renewing is close at hand, and then is the best time to make the distribution, unloading the ties right where they are wanted, and so soon before they are used that they need not be piled.

Where it is the practice to pile ties up after they have been distributed along the track they are usually piled loosely, sometimes cribbed, 10 to 20 in a place, near the track. In localities where timber is scarce railroad ties are in good demand for gate posts and for numerous other purposes, and on some roads it is necessary to watch the tie piles closely. In order to check up thefts of this kind it is the practice on some roads to place the same number of ties in all the piles, so that the foreman can tell if any have been taken. The loss is liable to be greatest from piles conveniently near the highway crossings. Certain remarks in the above relating to inspection and distribution of ties with reference to the seasons may not apply to some railways of the South and Southwest where the winters are mild or the ground does not freeze. Thus, on the St. Louis, Iron Mountain & Southern Ry., in southern Arkansas, it is the practice to inspect and renew ties twice each year—in the winter and again in the summer.

146. Handling Rails.—In the work of unloading rails, either at piles or when distributing for renewals, there are several methods in practice. The method of prying the rail over the edge of the car with bars and letting it slide off on skids is referred to in connection with track-laying. At points where a large number of rails are to be unloaded a derrick is sometimes erected, the rail being lifted from the car and swung around on the boom, to the pile or to a tram car. For unloading its 100-lb. rails the New York, New Haven & Hartford R. R. makes use of portable derricks which are attached to the side of the car. The derrick is constructed with a piece of rail for a mast and a piece of 1½-in. gas pipe for a boom. Two of these derricks are used with each car as it is unloaded, one being placed 4 ft. from each end of the car, on the side opposite that from which the rails are unloaded. There are two sliding clamps on the mast, one of which engages the top edge of the side board of the car and the other the lower edge of the side sill. With this device six men to the car unload the rails at the rate of about one each minute. There are two men who handle the rope tackle, two men on the car to attach the tongs and two men on the ground to release the load. When the car is unloaded two men can take up and transfer the derricks to another car in about two minutes. It is used both when unloading rails in piles and for distribution along the line, the car being moved a rail's length at a time in the latter case. The usual method of operation is to have two sets working simultaneously, unloading two cars at once. The average result during one season was upwards of 700 rails unloaded per day with 16 men, 20 men in one instance unloading 917 rails in a day, on main line under traffic.

In distributing rails for renewals it is here and there the practice on double-track roads to drop the rails onto the ballast between the tracks, two in a place. If the space between the tracks is evenly filled in, or if the ground is covered with snow of sufficient depth to serve as a cushion, and both ends of the rail are dropped simultaneously, such treatment is not liable to kink the rails; neither are they liable to be damaged if properly dropped on a well filled shoulder outside the tracks, as on single track, but the rails cannot in this way be kept even with the distance so well. A very common method is to haul the rails off the rear end of the car and lay them to place. As each car is unloaded it is cut off and left standing, so that other cars may be got at. Two men on the car, with light pinch bars, slide the rails onto dollies, one being placed on each side of the car at the rear end. By means of a rail hook and short piece of rope the men standing in the track grab the end of the rail in a bolt hole, pull it back, and, letting the end down, place it to the end of the rail just previously taken off, which is usually left on the ties, outside the track rail, or else on the shoulder near the ends of the ties. At a signal the car is then pulled ahead a rail's length and the other end of the rail is caught, as the car is pulled out from under it, and dropped in place outside the track rail. While the rail is being pulled back one of the men on the car should hold his bar in the frame of the dolly to keep the rail from running off the roller. With a dolly having a concave roller, however, it is not necessary to do this. Twenty men, divided into two gangs, can unload rails on both sides at the same time. Rails of 45 or 60 ft. length can best be pulled off the car by means of a chain, cable or rope, which is usually about 30 ft. long, with a hook in one end to attach to the rail, in a bolt hole, and a clamp or grab hook at the other end for attaching to the track rail, or for catching at the back of a tie. The rail is pulled off by moving ahead with the car, and drops onto the ties, in the track. No dollies or rollers are used on the car. The rails are easily thrown outside the track with pinch bars.

The practice of hauling rails off the cars with a drag rope anchored to the track is quite extensively employed for rails of 30 ft. length also, and it is not necessary that the rails should be let down with a gang of men. In order to break the fall a "platform car" or "tail gate" arrangement is quite commonly used. The former consists of an ordinary push car coupled on behind and carrying a large stick of timber or a few ties placed crosswise the car for the rail to drop on as it is pulled off the rear end of the train, thus letting the rail drop easily by stages. The tail gate consists of a panel of heavy plank, the top edge of which is attached to the sill of the car, the bottom edge trailing along on the rails, thereby forming an incline down which the end of the rail can slide gradually. For gondola cars two gates—one attached to the top edge of the car, with its foot resting upon the lower gate—might be a desirable arrangement. Another contrivance to break the fall is an iron yoke bolted to the coupler head at the rear of the car. This is crowned, so that when the end of the rail drops from the car it

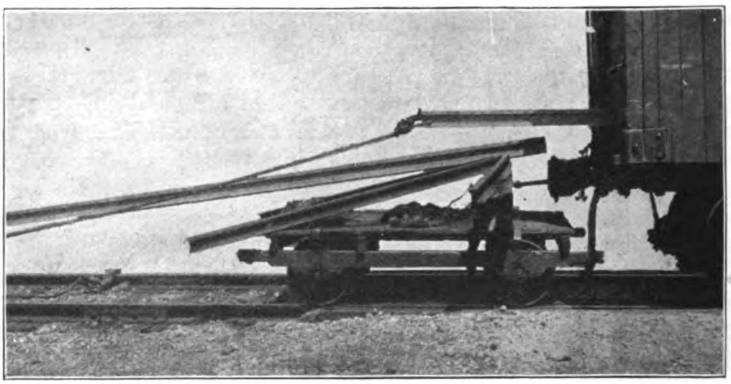


Fig. 365.—Unloading Rails With Drag Rope and Truck. C., M. & St. P. Ry.

will slide laterally off the yoke and fall clear of the track. It may be well to here explain that if one end of the rail rests upon the ground when it is dropped, the liability of injury is not nearly so great as it is when dropping the rail bodily, and rails as long as 45 ft. sag so low before the end drops upon the track that the rail cannot fall heavily, and on some roads no device is used to drop the rail by stages. It may be stated, however, that in general practice rails are handled with more care than formerly.

As for the details of the drag-rope method of unloading, the work is started by pulling back the first rail until its end stands even with a joint. The drag rope is then pulled back taut and anchored, and as the train pulls ahead this rail drops off end for end with the rail in the track. After that the clamp is applied to every track rail at a corresponding position relative to the joints; that is, if in pulling off the first rail the clamp is applied 10 ft. ahead of a joint in the track, then by applying the clamp in the same relative position in pulling off the succeeding rails, they will drop rail for rail with the ones in the track and just a rail length apart. By such a system of working, the rails are distributed in proper place and the extra work of carrying them ahead or back when they are set into place for coupling up in the track is avoided. In the case of short rails it is necessary to make allowance, which, however, is a matter of ready mental calculation. In usual practice two drag ropes are used, sometimes to unload on both sides of the track at the same time, and sometimes alternately on the same side of the track, so as to unload for one side without stopping the train, as explained further along. One of the roadmasters of the Chicago, Burlington & Quincy Ry. has used four drag ropes—two alternately for each side of the track.

On many roads the track department is seldom or never fortunate in receiving shipments of rails on flat cars. Especially is this the case in the West, where rails frequently come in box, stock or gondola cars. For unloading rails from box cars Mr. Edward Laas, with the Chicago, Milwaukee & St. Paul Ry., while roadmaster, put into practice a drag-rope method involving a number of interesting details. To prevent the rails from falling heavily upon the track a platform car is used at the rear of the train or car that is being unloaded, arranged with an incline to support the rails as they are dragged from the train and permit them to slide off easily onto the ballast shoulder at the ends of the ties, without the use of bars. This arrangement is illustrated in Figs. 365 and 366. Across the front end of a push car there is a timber, to the top of which is spiked a piece of rail about 9 ft. long, bent to a crown and bowed backward; and bolted to this at the middle there is a V-shaped piece of rail rearwardly inclined over the hind corners of the push car, forming wings which cause the rail to slide outward as the push car is hauled underneath it. On the rear end of the

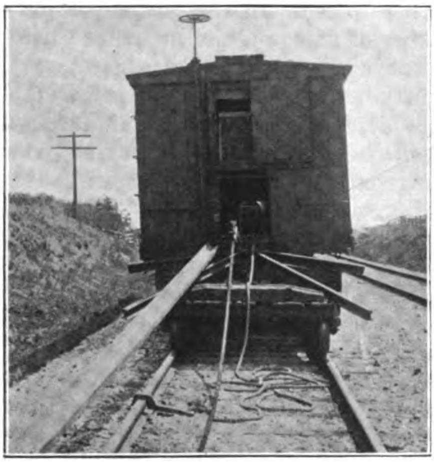


Fig. 366.—Unloading Rails With Drag Rope and Truck; End View.

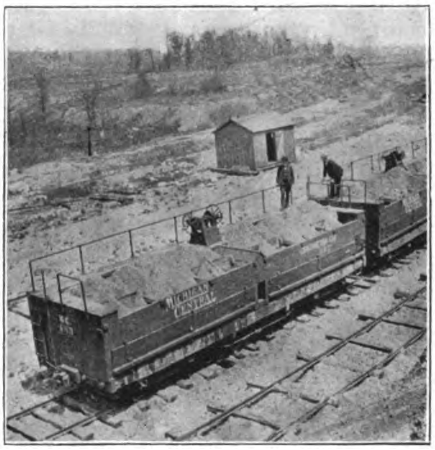


Fig. 367.—Torrey Ballast Cars Loaded, Michigan Central R. R.

push car, between these two wings, there is a piece of timber shod with an iron strap to prevent any possibility of the rail dropping between the wings. The coupling to the train is by means of a link in the rear coupler made fast to the cross beam. The whole arrangement is simple, cheaply gotten up and can be quickly lifted from the track and set aside. The Minneapolis, St. Paul & Sault Ste. Marie Ry. has used the same kind of an outfit.

In unloading rails two drag ropes, each 50 ft. long and 1¼ ins. in diameter, are employed alternately, and the train is moved slowly ahead without stopping. In order to accomplish this continual movement the rails for one side of the track only are unloaded at one time, those for the opposite side being unloaded during another trip. For handling the rails in this manner there is a gang of 11 men, three in the car and eight outside. Two of the men in the car stand in the rear end, on either side of the rear door, with a pair of tongs, to swing the ends of the rails into the opening. The third man stands at the front end of the car and handles a short bar to free the end of any rail which gets caught between other rails in the pile, in order that the rear end of the same, outside the box car, may be swung out of the track. Outside of the car, there is a man standing on the front end of the unloading truck to reach into the door to apply the hook. On each rope there are two men, one to pass the end of the rope up to the man who hooks it to the rail and another who carries and anchors the clamp. Besides the foregoing there are two men who seize the rail and push it outside the track when it is about half way out of the car, or when about to overbalance, and another man who carries a bar and walks behind to make sure that all of the rails are clear of the track after dropping upon the ballast. Occasionally one end of a rail may slide off the shoulder and cause the other end to stick up and obstruct the track. By this method 700 to 750 rails are unloaded per day, including the time lost in getting out of the way of the traffic trains.

If the rails are delivered on flat cars without sideboards they may be picked off the car and lowered to place by a crew standing on the ground. The proper way to take the rail from the car is to place a stake in one of the corner pockets and swing the end of the rail from the other end of the car so that men can get hold of it; this can be done by one man on the car working with a bar. The rail is then grasped by the whole crew, pulled from behind the stake, and let down to place. In this manner of unloading it is customary to run a long string of flats opposite the point where the rails are needed and have two unloading gangs walk from car to car and unload the rails. These gangs may work on opposite sides of the train; or they may work on the same side, beginning in the middle and working toward the ends of the train on one side, when they begin again at the ends and work toward each other on the other side, repeating the operation at each stop of the train. Of course, one gang can unload by this method to good advantage, or if it is desired to hurry the work four gangs—two on each side of the train—can be set to work. It should be noted that when unloading by this method calculation should be made for backing the train a sufficient distance to allow for the spaces between the cars. By observing the necessary distance, the train may be backed two or three times while the men are progressing the length of the train, so that the rails laid down will just about reach over the ground covered. This distance can be gaged by the engineer, allowing so many rail lengths for the idle space. In placing the rails on the ground it is always desirable, of course, to lay them as near as may be to the point where they will be used in the track, and hence it saves a good deal of labor if the rails are unloaded both sides of the track, instead of unloading both rails on the same side.

Dependence upon physical exertion for handling heavy material used in track maintenance has been gradually giving way to more rapid and more economical methods of work. One of the most toilsome operations in track work, when done by hand, is that of unloading rails and stringing them out along the roadbed for renewals, and this fact accounts for the many devices for and methods of unloading rails without direct lifting or lowering to place by hand labor. Aside from the contrivances already named there are several arrangements for lowering rails to the ground by means of side attachments to the car. The Byers rail unloader, which has been used on the Pennsylvania R. R., consists of three brackets with hooks of graduated length to attach to the stake pockets of flat cars or to hang over the sides of gondola cars. These brackets carry rollers, and when hung in place form an incline from front to rear. Upon being placed upon the rollers the rail runs back, and when the train moves ahead the rail drops to the ground and is set to place by a gang of men. In a similar way a trough-shaped or channel-shaped chute is sometimes used, being hung at the side of the car. The rail slides back until the lower end strikes the ground, and as the train pulls ahead the upper end of the rail is let down gradually as the chute is dragged from under it. For unloading rails from gondola cars a pair of skids are also sometimes used. The skids are hooked over the top edge of the side of the car, one pair at each side, so as to unload on both sides of the track. The rails are lifted and placed upon the skids by a gang of men in the car, and each rail slides down the skids under control of ropes in the hands of two men. Each rope is provided with a hook to attach to the end of the rail and is passed around a pulley at the top end of the skid. Each time the car is moved ahead the men pick up the bottom ends of the skids and carry them along. (See also § 211.)

Loading Rails.—The quickest and easiest way to load up old rails by hand is to get men enough to raise the rail at arm's length, high over the head, step up close to the car and throw it on broadside. It is dangerous for inexperienced men to attempt this method without careful instruction, but as soon as they get confidence in themselves, so that all will act together, there is no danger. The rail should be grabbed by the head and raised up by word. A good word to raise and throw by is: "Up—high—yo—heave!" It can be done in that many distinct movements. In order to pitch the rail to the farther side of the car the word should be given with greater force than when throwing to the near side. In all heaving and throwing by word, there being much of it done in railroad work, men should practice lifting heavily or lightly according as the word is given more or less loudly. The foreman should always be sure that every man fully understands what is to be done when the word is given; and he should explain that each man should act as though, independently of the others, he were throwing a piece of the rail equal in length to his share, according to the number of men who have hold of it. If a flat car is loaded with rails to be sent some distance it should be provided with end boards of heavy plank, and four stakes on each side.

The foregoing method of lifting and throwing rails applies to the work of loading upon flat cars or flat cars with low side boards. In times of busy traffic, however, it is frequently the case that flat cars are not available, and consequently gondola cars, or even box cars, must sometimes be used for this purpose. The work of loading rails into gondola or box cars by hand is a tedious operation, as they must be shoved through the end of the car. The usual method is to lift the rails and shove them over a dolly placed at the end of the car, but it saves a good deal of high lifting and hard labor to have a "loading truck" or "platform car" carrying a dolly at the proper hight to form an incline rollway onto the car. An arrangement of this kind is shown in Fig. 368. A push car is coupled to the rear gondola or box car by means of a stick of timber, and upon this push car there is a dolly blocked to proper hight for shoving the rails upon the car. A gang of men large enough to lift the rail then pick it up, shove it forward on the dolly until it reaches the end of the gondola, where men with tongs grab the rail and pull it forward. In order to handle the rails easily and quickly by this method, about 22 or 24 men are required.

An ingenious machine which dispenses with the services of a large gang of men in the heavy work of rail loading is in use on the Chicago, Milwaukee & St. Paul Ry., being designed by Mr. Edward Laas while roadmaster on the Chicago & Council Bluffs division. This machine is operated by compressed air supplied by the air brake system of the cars. It consists of a derrick operated by an air hoist, mounted upon a push car or truck 7 ft. wide and 10 ft. long, with a tool box on one end to carry such tools as are needed for the convenience of the work and to counterbalance the derrick while it is being moved. The derrick mast is a piece of 3-in. gas pipe screwed into a plate on one end of the truck and held by stays running to the four corners. The foot of the boom swivels on a pin set in the plate which supports the mast. The boom is 23½ ft. long and consists of two 2½-in. gas pipes trussed vertically with rods passing over the ends of wooden blocks, and braced laterally by rods running over iron struts set against the aforesaid wooden blocks. The hoisting cylinder is 8 ins. in diam. and 6 ft. long, on the inside. The piston rod carries a 17-in sheave wheel on a cross head guided by small wheels running on the two pipes of the boom. Hoisting is done by means of a two-part ⅝-in. wire cable made fast at the end of the boom and passed around the piston sheave wheel so that for a full travel of the piston the cable lifts 12 ft. The pulley at the end of the boom is 17 ins. in diam. In rear of the mast there is a storage reservoir 3 ft. high and 2 ft. in diam. which is placed in connection with the air brake

Fig. 368.—Loading Rails Over a "Platform" Truck.

pipe of the cars by disconnecting the hose between two cars and coupling on in the ordinary manner. This reservoir has a capacity sufficient to lift two rails after the air from the train has been cut off. The hoisting cylinder is operated by means of an air cock. The end of the boom stands 19 ft. above top of rail, and when rails are being lifted the end of the derrick truck opposite from the derrick is held down to the car by means of two adjustable hook clamps attached to a beam running crosswise the truck and set to catch the under sides of the side sills of the car. The derrick is designed to lift a load of 1500 lbs. In handling rails the derrick truck is run to one end of a flat or gondola car (Fig. 369) and clamped in position for loading upon the adjoining car. As each car is loaded the machine is pulled back one car length, small gang planks being used to bridge the opening between the cars. The machine can be pushed over the cars by five men, but in usual practice it is pulled by cutting the train one or two cars back of the machine and attaching a rope to the last car coupled with the locomotive. One important advantage in the use of the machine is that it may be operated to load a whole train of empty cars without the necessity of shifting.

In loading rails six men are required, and the usual practice is to pick up the section gang where the rails are to be loaded. In the distribution of this force there is one man at the air cock (usually the foreman), two on the ground to attend to the lifting tongs and to prevent the rail from swinging; and three on the car, one of whom handles the lifting hooks and the other two swing the rail to place while the man handling the air lowers the derrick cable. While the work of loading is in progress the boom is stayed to one side of the gondola or flat car so it will not swing too far out. When a rail is lifted the boom is swung by merely swinging on the rail. After some experience it was found that the most convenient device for attaching to the rail was a single pair of tongs at the middle. As a matter of record this machine has loaded 65 rails in 30 minutes. The cost of labor in loading 608 rails, or 18,240 lineal feet, of 75-lb. rail, on one occasion when the work was interrupted by running to sidings to clear for trains, was $8.75, or less than 1½ cents per rail.

When laying new steel on double track it is the practice on this road to throw the old rails into the space between the tracks, so that with this machine the rails can be loaded with the work train standing on either track. When loading the rails into box cars they are first lifted onto a flat or gondola car and then run into the end of the box car on a series of dollies placed at an incline. As is obvious from the illustration, the machine can be used just as conveniently in unloading rails as in loading them. Machines built to a later design have the wheels inside of the side sills of

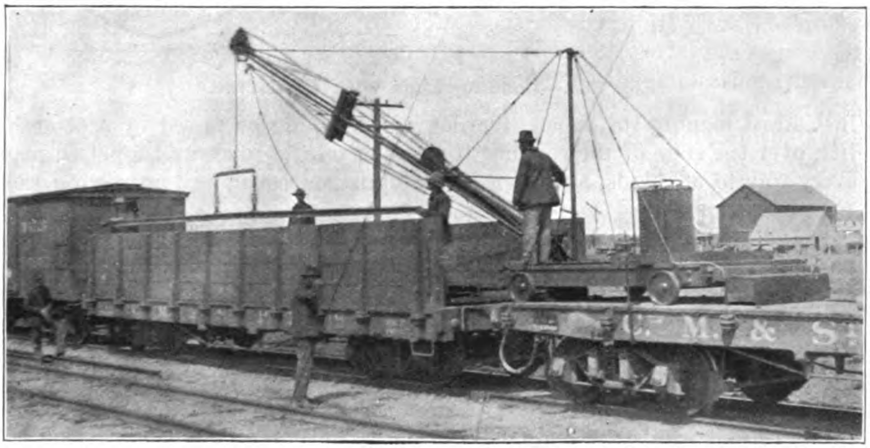


Fig. 369.—Loading Rails With a Laas Derrick, C., M. & St. P. Ry.

the truck, where they are out of the way and cannot catch the side of a gondola car when being hauled over the train. The "American" rail loader is a similar machine, and is described in § 218 Supplementary Notes.

147. Loading Logs.—On roads where logs are handled as traffic it sometimes becomes necessary to reload logs which have rolled off the cars; and on any road running through forests large trees will occasionally fall across or into the cuts and have to be removed. One way of handling trees is to roll them into the track, drag them out of the cut with the work train, and then roll them down the embankment, if there be one near. If the logs or trees must be loaded onto cars, however, it may as well be done in the cut, at the first handling, or once for all. For lifting the logs the derrick or wrecking car can be used, of course, but with this means only one car can be loaded before it becomes necessary to switch the cars in order to get an empty car next the derrick. A convenient method quite frequently resorted to is the use of a parbuckle, the hauling being done by the engine or train. The arrangement is quite simple and is shown in Fig. 370. The car to be loaded is placed opposite the log and the brake set. A rope is then passed around the log, near one end, one part (A) of which is passed over the car floor and, after being looped around the rail under the far side of the car, is made fast to the snatch block C. The other part (B) is passed through the snatch block and is pulled on by the locomotive, the part A remaining stationary. Two sets of ropes and snatch blocks being arranged as shown—one set near each end of the log—both are pulled on at the same time, so that both ends of the log come up evenly. On the car the log should be rolled onto skids, so that the ropes can be easily taken from under it. It is better to use a $\frac{3}{4}$ or $\frac{7}{8}$-in. wire rope than a hemp rope, as a hemp rope would be rapidly worn out in being drawn over the edge of the car. A chain might be used for anchoring the snatch block to the rail,

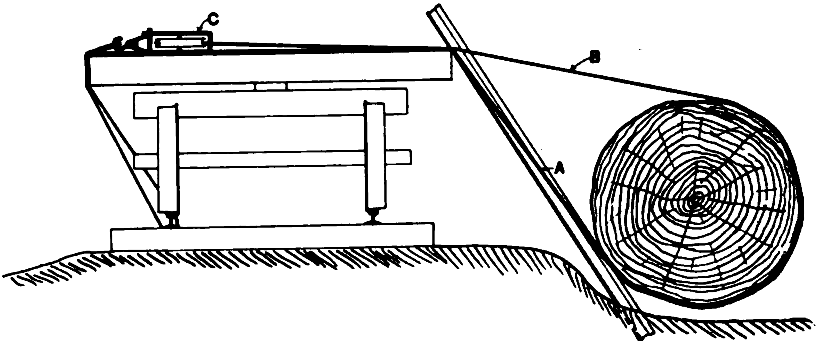


Fig. 370.—Loading Logs with Parbuckle.

instead of looping the rope. The log can be slung or raised by a straight lift, over the edge of the car, but it is easier on the ropes and a better plan every way to use skids, as shown in the figure, pieces of rail answering well for such purpose.

148. Handling Ballast and Filling Material.—Most railway companies which have the opportunity avail themselves of a bank of gravel on or somewhere near the line, as a source of ballast supply. When running a spur into a gravel bank it should, if possible, be made long enough to extend past the bank. If the loading is to be done by steam shovel the "tail track" should be at least as long as the train of cars which the engine is expected to handle in the pit. The practice of taking out gravel in piecemeal sections spoils the bank for the most convenient methods of loading. The end which swings into the bank cannot easily be kept even with the rest as the work progresses inward, and a nasty curve results which sooner or later brings things to a halt. In order to get more gravel the track must then be thrown back, over the ground on which it has advanced, and extended past the pit so made; and thus the work goes on at continual inconvenience and disadvantage. It is a better plan to use more rails when the track is first laid, as then the track will not have to be moved so frequently and, having room to shift cars, the face of the whole bank can be worked away evenly. It usually happens that by the time a railway company gets through with a gravel bank the amount of material taken out has proved to be several times the first estimate. In case the track cannot be run past the whole length of the bank, the far end of the spur can be kept even with the rest by shortening it a rail's length at each move inward; or by running up the far end and taking out the bank to a less depth there to compensate for the extra amount of material which must be moved at the end of the last car. In loading gravel or filling material it is sometimes desirable to make a cut straight into the face of a bank and extend it for some distance by loading one car at a time at the head end of the track. One way to keep the track even with the work without frequently laying short pieces of rail is to use extension rails bottom up. Each extension rail is laid outside the last rail that is coupled in the ordinary manner, with the base of the former overlying the head of the latter. This arrangement brings the upturned bases of the extension rails to gage, and in line with the gage sides of the rails laid in permanent style; and as the excavation advances they are merely shoved ahead while a car is being switched. After the pit has been extended a rail length the end rails are laid workwise and inverted extension rails are placed temporarily as before. Sketch B, Fig. 370A, shows the arrangement, the extension rails being shown in solid section. To make the rails secure against overturning, a switch rod of suitable length might be put on at the end, but such is not generally used.

In order to keep gravel ballast free from loam it is usually necessary to strip the top soil from the bank. It is sometimes considered that in deep cutting the mixture of top soil is so slight as to be negligible, but if the gravel is otherwise clean and the soil overlying it of appreciable depth, and particularly if there is a sod, it will generally pay to strip it. Stripping is usually done by teams and scrapers. Strippings makes good material for filling on the slopes of embankments where it is desired to get seeding started, and one way to dispose of it at a gravel pit is to scrape it to the front side and load it up for that purpose when making the first cut through. It is also good material for placing under track that is being lifted in stages, as in raising grade through a sag, or in track elevation. Railway companies, when loading gravel on private property, are sometimes obliged to enter into a contract to replace the soil on the land after excavating the gravel to a stipulated depth. One way in which this is done is to scrape the soil to the edge of the bank and cast it to the foot of the slope each time a cutting is made through the bank, or as often as each two or three cuttings are made, thus moving the material in strips of a width corresponding to convenient scraping distance. The soil thrown down the

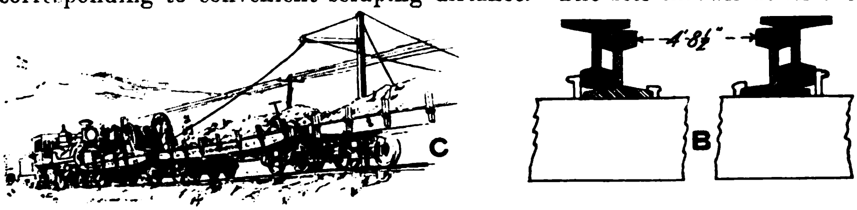


Fig. 370 A.

slope is then spread over the bottom of the pit, usually with teams and scrapers. If the pit is narrow the soil may be scraped into a long heap, either to the front side or to the back side, or half in each direction, before the excavation of the ballast is started, and then spread over the bottom of the pit after all the work of excavation is completed. Another plan that is sometimes followed is to haul in loam on cars from the outside, and unload it behind the steam shovel or loading gang as each cutting is made, the empty cars being loaded with gravel on the return trip. It is sometimes quite convenient to do this, the material being available where work is in progress at widening cuts through loam or in making original cuttings for a changed location.

When loading gravel by hand it is well to put about 2 ins. of elevation in the rail farthest from the bank. This inclination in the track will tilt the flats toward the bank and very much facilitate the work of loading. By loading a little from the side farthest from the bank, or by handling the material over on the car, 15 cu. yds. of gravel can be put on a 33x9-ft. flat without side boards, and it will ride the car a good distance without spilling off to any extent; with side boards 12 ins. high the load can be made 20 cu. yds. By going deeper than the bottoms of the ties at each move, the hight of the bank may be continually increased, thus necessitating less frequent moving; and also it continually leaves behind a quantity available for finishing out the far side of the car. It is best to load the cars to their full capacity, if it can be done conveniently, as under such a plan fewer cars are required to move the material and, as a matter of course, there is less shifting to be done. If the gravel is thrown upon the cars carelessly, with no view to getting loads of good size, or if clear space is reserved at each end of the car for standing room, 10 or 11 cu. yds. will be about the average load. Since the track must be moved frequently, little attention need be paid to the manner of its support. Bring the ties approximately to an even bearing by throwing gravel or blocks of wood under them and let it go at that, without much regard to surface. Much time spent on such track is time thrown away. Ordinary judgment will suggest to the foreman when the track is safe enough for slow-moving cars or the locomotive.

In ordinary gravel, 20 cu. yds. is a fair amount for one man to load on a flat car by hand, in a day of 10 hours. Shoveling gravel becomes more tedious than tiresome, and most men, as time goes on, will fail to keep up the gait which they started out with during the first few days, especially if too many get together at loading the same car. Men paid by the car-load, however, will gradually increase the amount loaded per day and are not so apt to complain about the work being hard. Loose gravel, if fine, seldom needs picking down. For the sake of a change men sometimes get into the foolish habit of climbing up the bank and picking it down from the top. The more the bank is picked away at the top the more gradual becomes the slope, of course, and therefore the greater the necessity for using the pick at the bottom or foot of slope. Picking, if done at all, should be done at the bottom, as fast as the loose material is shoveled away. The weight of the material above will then bring down the top, of itself. Large, round stones found in a gravel pit are generally disposed of easiest by burying. Dig a pit as close to the boulder as possible, roll it in and cover it over.

During winter time, when the ground is frozen and section men cannot do much on the track, in place of laying off part of each section crew for the time being, it will pay to make up a work-train crew (if there be no regular one), by calling one man or more from each section, and with it to spend a week or so hauling out cinders along the road. The cinder piles at water stations and other places can in this way be cleaned up and the material utilized to advantage by being spread over the shoulder, outside the tie ends, to a depth of 2 or 3 ins. Money spent in this way will be more than refunded by the decreased cost for grubbing weeds, which will result from the use of the cinders during the following summer; and then there are usually many places where the shoulder needs strengthening. If by keeping the winter forces at work as steadily as possible the results can be made to show substantially by way of decreased labor expense during the following summer, the policy is certainly a wise one to follow.

Steam Shovel Work.—Sometimes a question arises as to the advisability of using a steam shovel for loading gravel. There are circumstances and conditions under which a steam shovel is, of course, a very economical means for loading gravel, and there are others when hand labor will load cheaper than the machine. First, the question must be settled as to whether the quantity of material to be handled will warrant the outlay for a steam shovel; next, whether, under the conditions, the steam shovel can compete with hand labor. A steam shovel in gravel is worked to best advantage where the bank is high, as then its progress is not so frequently interrupted in moving ahead. There should also be ample ground beyond the pit for the tail track, so that a string of cars may extend past the machine when it is working at any point along the bank, else the time taken up in switching will delay the work to a great extent. Under favorable conditions a steam shovel with a 1½ or 2-yd. dipper will load about 125 flat cars per day, or 1100 to 1200 cu. yds. In many cases this record has been far exceeded, machines with 3 or 3½-yd. dippers loading more than 2000 cu. yds., but the average machine under average conditions will not keep it up day after day. There are certain conditions, as where the bank is short or shallow, or the work train service is much interrupted by the traffic trains, so that time is lost waiting for empties, where it is not safe to put the average day's work higher than 700 or 800 cu. yds. The expense of running a steam shovel per day is not usually less than $25, including cost of wear and tear, fuel, men to operate it, and pitmen. There is required, or, at any rate, usually employed, in addition a locomotive with its engineer, fireman, brakeman and conductor, in constant attendance, making the cost to the company of running the machine not less than $50 per day, or the wages of about 40 laborers. Now, in fair gravel, 40 laborers can load 800 cu. yds. per day, and no locomotive will be needed. The locomotive which hauls the gravel away can do the necessary shifting of cars, whereas to get the gravel away from the machine requires two—a matter of importance for a small road to consider. An occasional breakdown or delay of some kind to the machine is bound to occur, while with a force of laborers there is no breakdown, and the right kind of foreman will see that there is no delay. It is thus seen that, to compete with hand labor, the machine must work under favorable conditions. In material which would require much picking, if loaded by hand, the advantage is more likely with the machine in any case.

The expense of operating a steam shovel, together with a locomotive working with it in a pit, is itemized below. The amounts of fuel used, prices for the same and for labor of the various kinds are averages of figures obtained from similar work on several roads. One night watchman is supposed to take care of both locomotive and steam shovel. Six pitmen are allowed for leveling off the surface and laying track ahead of the machine, handling the jacks, picking and poling down the slope and other miscellaneous work. A steam shovel in a high bank might get along with four men for this work, but in shallow cutting as many as eight are sometimes required. No allowance is made for foremanship, as the cost would be the same for either hand or machine loading, and therefore this item is not needed for the comparison. The cost also of throwing over the loading track would be taken the same in either case, although there is always more tinkering with tracks where a steam shovel is used than where the loading is done by hand. Allowance is made for a conductor and brakeman in the pit. In ordinary work two men will be needed to do switching in the pit, in order to keep the machine loading as constantly as possible. The conductor is thus supposed to do a brakeman's work, his work in the capacity of conductor being light. He should endeavor to so arrange his cars that switching may be done while the machine is being moved ahead. The locomotive used in the pit should be supplied with air or steam driver brakes, to facilitate close movement and rapid handling of the cars while they are being loaded by the machine.

Daily Expense of Locomotive in Pit.

Use of Locomotive	$ 8.00
Coal, 2 tons @$2.25	4.50
Oil, 14 cents; waste, 5 cts.	.19
Water, 50 cts.; Kindling, 20 cts.	.70
Half watchman	.88
Ordinary repairs	.55
Engineer's wages	3.75
Fireman's wages	2.25
Conductor's wages	3.25
Brakeman's wages	1.75
Total	$25.82

Daily Expense of Operating Steam Shovel.

Use of shovel	$ 6.00
Coal, 1800 lbs. @$2.25 per ton	1.80
Oil, 20 cts.; Waste, 5 cts.	.25
Water	.25
Engineer, 1/26 month @$125	4.81
Fireman, 1/26 month @$60	2.31
Cranesman, 1/26 month @$90	3.46
Half watchman	.87
Six pitmen	7.50
Ordinary Repairs and Supplies	.75
Total	$28.00

The work of loading dirt can usually be done cheapest with the steam shovel, as in such work the shoveling is more difficult than in ordinary gravel, and the machine can outstrip hand labor more easily than it can in gravel. In widening cuts, where the cars are loaded on main track, the advantages in favor of the machine are apparent. In such case a locomotive is required with hand labor, the same as with the machine; and while the train must be away to give track rights or to unload, the loss from the machine standing idle would be less than that for a large crew of laborers. And then, too, the machine can generally utilize at least part of such time in moving ahead. In widening out cuts for double track the machine can reach the main track from the far side of the excavation, whereas hand shovelers could not cast the material over the whole distance.

A steam shovel works upon a short piece of track laid in sections 4 to 10 ft. long. It is advanced by taking up sections in the rear, carrying ahead, and laying them down at the front. Lengths of 6 ft. are most commonly used, the rails being held to gage by tie bars and spliced with short splices with one or two bolts or keys in each. Another arrangement commonly in service is to have the sections of rails spiked to 6x12-in. stringers which rest upon ties or blocking at the joints. The track is held to gage by tie rods hooked into eye-bolts in the sides of the stringers, and the sections are joined end to end by tie rods across the joints, hooking into eye-bolts in the sides of the stringers, so that it is not necessary to splice the rails which rest upon the stringers. Another form of shovel track has joint ties with wrought iron chairs bolted or spiked fast. The rail sections fit into these chairs and carry the shovel without splices or tie bars.

In working a steam shovel in a bank considerably higher than the reach of the dipper it is desirable to have the material slide down to the shovel gradually. In a gravel pit the working of the machine, with perhaps a little extra labor at picking or poling the face of the bank, is usually all that is necessary to bring the material within convenient reach of the dipper as fast as it is needed. In a high bank of hard earth, however, the material will frequently stand to a vertical face until undermined by the shovel and then suddenly cave off in large masses, burying the shovel or jeopardizing the lives of the pitmen. Where trouble of this kind is liable to occur it is common practice to loosen the bank or "shoot it down" with explosives, in advance of the shovel. In doing this holes are bored, say a rod apart and to a depth and at a distance back from the edge of the bank depending upon conditions, and loaded with blasting powder after exploding a stick of dynamite in the bottom of the hole to spring it to larger cavity. In some cases one hole is fired at a time just in advance of the shovel, the latter backing off far enough to escape the falling bank; and sometimes a number of holes are fired simultaneously, bringing down a long stretch of bank in rear of the shovel to be handled when it backs up for a new cut.

In order to economize in cost of engine service, a team of horses is frequently used to spot the cars at the shovel. The heavy shifting is attended to by the road engine that hauls away the material, and if the grades in the pit are easy the plan works fairly well. In providing loading tracks for steam shovels there are two general arrangements. The ordinary plan is to have only a single track through the pit, and after the shovel reaches the end of its cut this track must be thrown over to the bank before the shovel can be run back and begin another cut. Where the cut is a long one this throwing of the track takes a good deal of time, frequently a half day for a gang of a dozen men. In order to avoid delay to the loading this work is sometimes done in the night. By what is known as the "double-track" plan, a track is laid in behind the shovel as fast as the latter advances, and as soon as the shovel reaches the end of a cut it may immediately be run back to begin another cut, the only delay being to connect the new loading track with the main siding where the shovel starts in again. In one instance where this arrangement was in practice on the Canada Atlantic Ry. a shovel was moved back 1300 ft. and put to work again in 27 minutes from the time she ran out of the cut. The material for laying the track which follows up the shovel is obtained by taking up the old loading track for the previous cut and carrying it across piece by piece. This is done by the pit crew, which usually has more or less time to spare, and thus the laborious work of throwing track is avoided without extra help or delay to the work of loading. This plan of working requires sufficient material for a double track the length of the pit. In some instances a switch is put in at the starting end, so that the track behind the shovel can be used to hold the tank car, where it can be available while the shovel is working. This arrangement is something of a convenience, for the usual plan is to push the water transport and fuel supply cars back on the tail track, or couple them behind the string of empties to be loaded, and then spot them opposite the shovel or the shovel tender when the engine pulls out to switch the loads, so that water and coal can be taken while the train is away. It is also usual to attend to taking on coal and water during the noon hour and at night. Where the steam shovel is working lower than the loading track, as when cutting down summits on main track, the coal can be run over on a chute. Plenty of track room in a gravel pit is a useful provision, as with a good supply of empty cars on hand the steam shovel can keep going regardless of delays to the road train or trains that are hauling the material.

Dredging Gravel Ballast.—In order to obtain suitable gravel for ballast within reasonable hauling distance, railway companies sometimes find it necessary to resort to unusual methods of excavation. Good deposits of gravel are sometimes found on low-lying land or in the beds of streams, so that the material is available only by taking it from under water, by dredging methods. The Choctaw, Oklahoma & Gulf R. R. is a road whereon such a condition prevails. Gravel banks, as they are ordinarily found, do not exist, but along the Memphis division of the road a supply of good material has been taken from the beds of streams, many of which are apparently dry about two thirds of the time. In times past the company has contracted for the loading of this gravel by teams, over traps, for 12½ cents per cu. yd. This cost was exclusive of trap material and the labor account for ditching. Delays incident to rain storms, floods, etc., were troublesome, and in addition there was a great deal of annoyance arising from the cutting down of the team force on account of sore hoofs. and from the large amount of skeletonizing of the track in advance of delivery of the gravel, owing to the impracticability of keeping the supply properly regulated to the demand.

As these difficulties made it desirable to devise some method of machine loading adapted to the conditions, the matter was taken in hand by Mr. John H. Harris, general superintendent, who concluded to try the method of dredge working, whereby the machine could be floated and cut its own channel along a siding used for a loading track. An ordinary Bucyrus steam shovel with a 1½-yd. dipper was placed upon a barge 50 ft. long, 20 ft. wide and drawing 27 ins. of water, constructed of old stringers taken from bridges rebuilt, and was launched into a "hole" or pond excavated for the purpose, the scene of operations here described being the bed of Crow creek, between Madison and Forest City, Ark. The steam shovel was run aboard on a track spiked to the deck of the barge. There was a spud at each corner of the barge to steady the outfit and hold it to its work, and the only change made in the steam shovel was the lengthening of the dipper arm to enable it to reach a distance of 24 ft. from track center, thus giving the barge considerable latitude of movement in its channel. The position of the shovel on the barge (Fig. 371) was regulated by means of stay chains on either side, snubbed to posts upon the barge, and in addition to these chains there were permanent beams securely bolted across the rails at the ends of the barge as a safeguard against dropping the shovel overboard. The shovel was capable of working to a depth of 10 ft. under the water. In moving ahead from one working position to the next the barge was shoved against the gravel slope ahead, this being done in two or three minutes, by two men, who

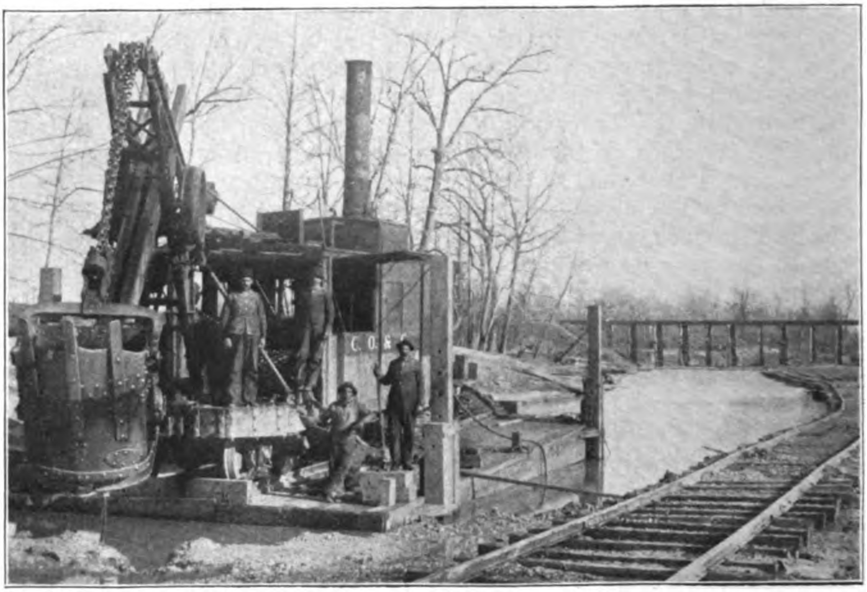


Fig. 371.—Loading Gravel Ballast with a Floating Steam Shovel, C.,O. & G. R. R.

would lift the spuds and push the barge ahead with poles, after which the spuds would be dropped and the shovel moved ahead on the barge to its working position. When the shovel had worked out all the material within reach of any certain position it would be moved back a few feet on the barge, lifting the bow and causing the barge to float at both ends. The barge would be then backed off a few feet and held to position on pinned spuds while the shovel cleared out the channel. The barge as it appeared in the figure was working up stream, the fall of which is at the rate of about $\frac{3}{4}$ of one per cent. The plan of work was to proceed as far up stream as the point where the shovel could no longer reach the top of the cars, after being blocked up on its trucks to gain something more in hight. If it was desired to go farther, the water would be raised by damming the channel behind the barge and then the work would proceed as before. The gravel obtained in this way was of excellent quality, being free from mud or clay, and as the dipper was lifted through the water the excess of sand was washed out, the quantity remaining being usually less than 5 per cent. When plenty of empty cars were on hand the gravel was loaded for $1\frac{1}{4}$ cents per cu. yd.

The Baltimore & Ohio Southwestern R. R. has employed an ordinary dipper dredge for loading gravel ballast. At a point on the Wabash river, in Illinois, four miles from Vincennes, Ind., a gravel ridge 12 to 16 ft. high on a low prairie had been taken off with a steam shovel to the water line. It was then found that below the water there was a deep deposit of gravel suitable for ballasting purposes, and to save buying more land

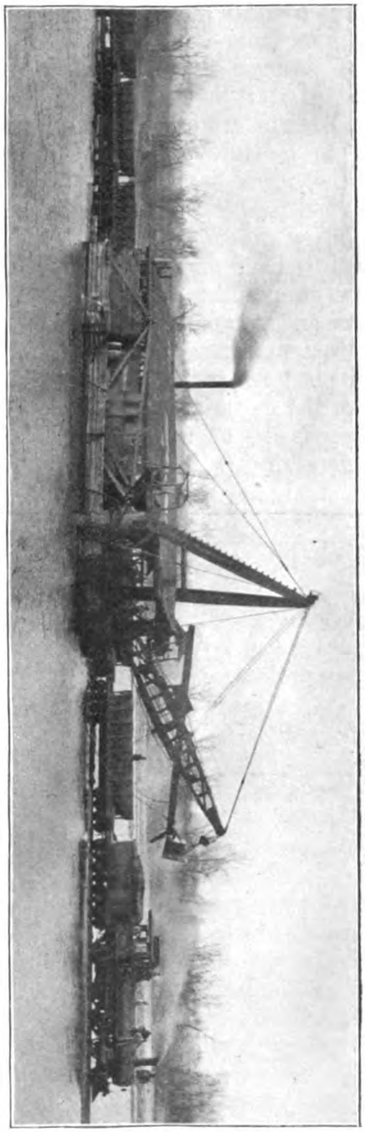


Fig. 372.—Loading Gravel Ballast with a Dredger, Baltimore & Ohio Southwestern R. R.

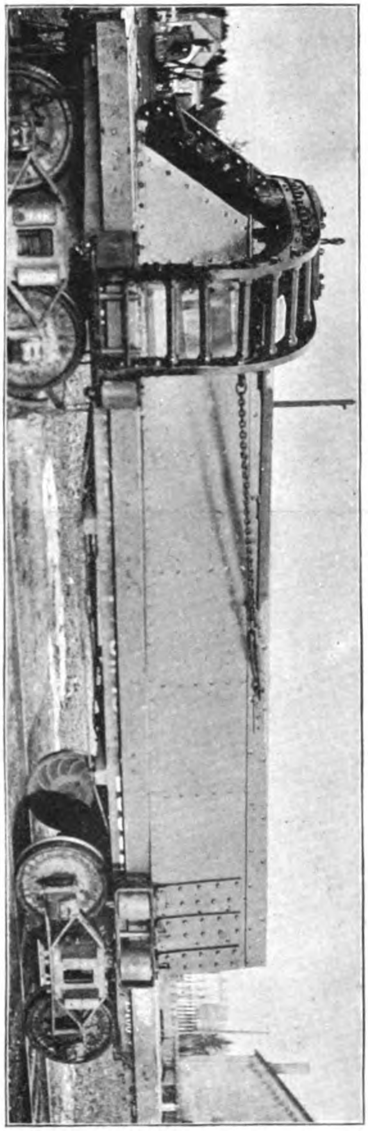


Fig. 373.—Warner Unloading Plow, Northern Pacific Ry.

it was decided to put in a dredge and take out a deeper cut. Accordingly a $2\frac{1}{2}$-yd. Marion dipper dredge was put in and gravel was excavated to an average depth of 24 ft. below water line. Figure 372 shows the dredge in operation. The cars hauling away the material were Rodger ballast cars of 80,000 lbs. capacity. At the time the photograph was taken the whole region was overflowed to a depth of about 18 ins., and in order to lay the track high and dry, and throw it over on dry ground when the dredge reached the end of the cut, the dredge deposited gravel enough on the far side of the track to raise the roadbed above the water. As the ground had been formerly worked over by a steam shovel the gravel taken up by the dredge was free from soil.

Loading Gravel in Moderate Quantities.—In loading gravel for ballast renewals, or for any purpose where the quantity of material needed during each season is comparatively small, there frequently arises some question regarding the economy of working a steam shovel. The operation of a steam shovel requires an extra engine and crew to haul the ballast away from the pit, for distribution along the line, since the quantity which a steam shovel will load each day is rather more than can be disposed of if it is intended to economize in cost of hauling by using the local freight trains. In employing a steam shovel it is therefore necessary to go into the work somewhat extensively while the work lasts. On the other hand, where hand labor is employed the cost of loading is a considerable figure. Nevertheless, where it becomes desirable to forego the heavy expense of a steam shovel and work trains the plan of loading gravel by hand and distributing it by local freight trains is very commonly found in practice. One method of loading at medium expense is with teams and scrapers, dumping into cars through traps. This method is followed on a number of roads. The arrangement for the purpose consists of a platform or staging built over the track, with an opening through which the material can be dropped into the cars. The construction sometimes consists of a temporary bridge over the loading track or siding, the bridge stringers being laid upon cribbings of ties which serve for the

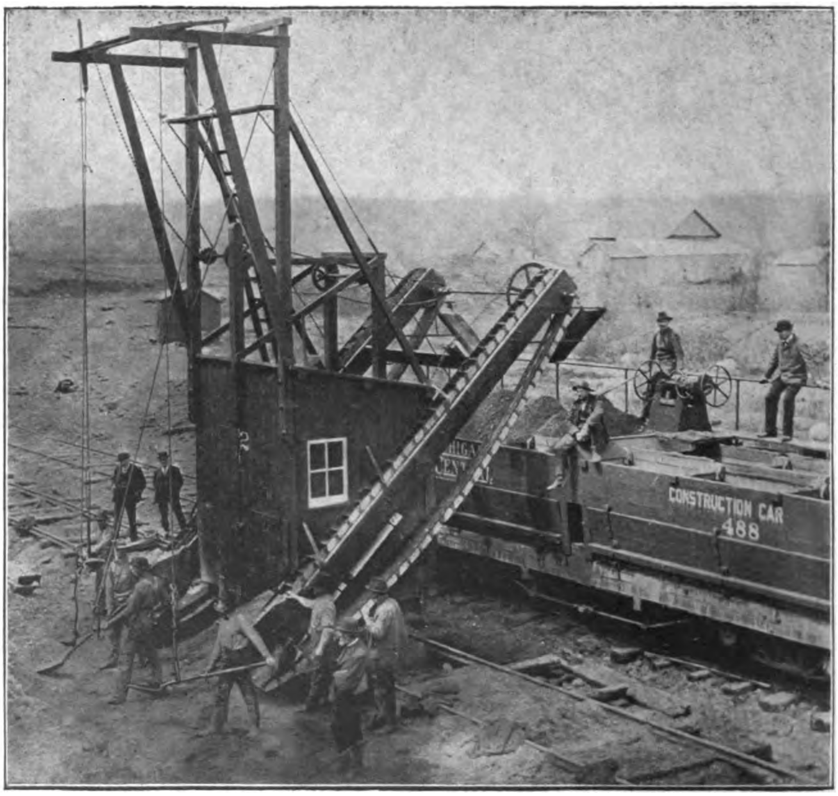


Fig. 374.—Torrey Ballast Loader, Michigan Central R. R.

abutments. As the temporary use of the material in this way does not injure it for other purposes (except for the wear to the floor planking), the expense for the lumber is only a trifle. The most favorable location for traps is where they can be built over a side-track along the foot of a hill or bank, or along side hill, as then the material can be scraped into the cars without elevating it. The cost of loading gravel in this manner is 8 cents, more or less, per cubic yard, depending upon the lay of the ground, the distance the material must be hauled, the quantity that can be loaded before it becomes necessary to move the traps, etc. In one instance where the average haul of the scrapers was 175 ft. and the average distance traveled per round trip over the traps 600 ft., the average quantity of material handled per team was 50 cu. yds. per day, making the cost of loading 7 cents per cu. yd. Most of the scrapers were of the wheel type, only a few being drag scrapers.

A method of team work similar in some respects to the foregoing was at one time practiced by the Calumet Improvement Co., at Plainfield, Ill., and in some other places, for loading gondola cars. The material was excavated by teams and scrapers and conveyed to the gondola cars by an endless belt driven by a portable or stationary engine. The belt was composed of steel plates and was made to pass under a low platform onto which the gravel was hauled and dumped upon the belt. The other end of the belt was elevated, so that the material was dropped into the cars as they were hauled along under it or let down an incline by gravity. The teams were driven around in a circle, so that several could be worked within a close radius. In this way the material was handled quite rapidly and cheaply, so it is stated, but no figures are at hand. One of the principal objections of this method of loading was the fact that it failed to mix the gravel properly. As the scrapers were necessarily worked on the upper surface continually, the gravel was taken off in layers, or practically as it lay in the strata in their natural positions, so that some cars were loaded with the fine material and others with material from the coarser layers. In loading gravel by hand or by steam shovel the material is taken from or near the bottom of slope, so that, as the gravel from the various layers rolls down the slope, all sizes become quite thoroughly mixed, which is the condition most suitable for the purposes of ballast.

An interesting scheme for loading gravel is a combination of machine work and hand labor devised by the late Chief Engineer A. Torrey, of the Michigan Central R. R. In general terms it may be stated that the arrangement enables the loading of smaller quantities of material than would be handled by a steam shovel working to its capacity, and at a cost for loading which approximates that of steam shovel work. The loading outfit (Fig. 374) consists of an elevator or loading car, which occupies a track at the foot of the gravel bank and conveys the gravel to the ballast car standing upon a track 12 ft. distant from the first, center to center. The material is conveyed from hoppers into which it is deposited by shovels of large size, handled by the men with the assistance of power to lift the loaded shovel to a level with the hopper. The loading car is 9 ft. long, 8 ft. wide, and is housed over. The source of power is an upright gasoline engine of 5 horse power. At each end of this car there is a rubber belt conveyor running over 20-in. pulleys. The belt is 10 ins. wide and carries buckets 3 ins. deep, 3 ins. wide, 9 ins. long across the belt and set 9 ins. apart on the belt, being formed of steel plates riveted to the belt, with overlapping plates at the sides, so that no openings are formed as the belt turns around the pulleys. The belt has a velocity of 180 ft. per minute. The hoppers are 10 ft. 4 ins. apart between centers and 3 ft. above the ties, and they extend 3 ft. beyond the rail. Attached to the upper part of the elevator car there is an overhanging frame carrying a horizontal shaft 24 ft. above the track and 4 ft. beyond a perpendicular line through either hopper, or 7 ft. beyond the rail. On each end of this shaft there is a double crank, or pair of oppositely-extending crank arms, from which are suspended two ropes, to the bottom end of each of which there is attached a scoop shovel, with a long handle, the scoop being the size of an ordinary grain scoop, holding 2½ to 3 times as much material as an ordinary track shovel. The rope is attached to the scoop about 1 ft. from the blade, and adjustment in the length of the rope is obtained by a strap and buckle, which forms the means of attachment. Each crank is 18 ins. long, from center, which gives a 3-ft. stroke to the rope which lifts the scoop. The modus operandi of a single scoop is as follows: The length of the rope to which the scoop is attached is so adjusted that while the crank is passing under the center the scoop is lowered to about the level of the bottoms of the ties, and is then thrust into the bank of gravel, by the man holding the handle. As the shaft revolves it lifts the scoop to the hight of the hopper, the shoveler meantime swinging it to position over the hopper, into which the scoop is emptied by revolving the handle and overturning it. As the crank descends the scoop is again lowered to receive another load. At the other end of the same crank the rope attached manipulates another scoop in the same manner, the two scoops being worked 180 degrees apart in phase, one scoop being at the lowest point of suspension, or at the point where it receives its load, as the other scoop reaches the highest point of suspension, at which time its load is being delivered to the hopper. Both scoops suspended from the same crank are unloaded into the same hopper. At the other end of the revolving shaft the same evolutions occur, there being two suspended scoops lifted and lowered alternately as the crank revolves. The cranks on the two ends of the revolving shaft are set 90 degrees apart, or at right angles, as the shafts of a locomotive, the idea in this arrangement being to balance the work on the engine, since if the cranks were set together there would be two loaded scoops to be lifted simultaneously while the other two scoops would be empty. The reach of the scoops into the bank is 10 ft. from the hopper, at the level of the bottoms of the ties.

The revolving shaft to which the suspended scoops are attached makes 10 revolutions per minute, so that each shoveler delivers to the hopper 10 times each minute, the gait being set by the machine. The speed of the shaft, however, can be regulated at will. The ordinary rate at which a shoveler will load gravel onto a flat car, from the ground level, is about eleven shovelfuls per minute. Working in this manner a crew of six men and a foreman, including four shovelers and two men to pole down the bank, have loaded 300 to 350 cu. yds. of gravel per day of ten hours, when cars were available for continuous work. The engine burns five pints of gasoline per hour, costing about 12½ cents per gallon. The elevator belts and engine have a capacity for carrying about three times the amount of material here mentioned. The gravel cars are run to position opposite the loading machine by gravity, half of the car, or the space from the middle to either end, being loaded in one position of the car. The gravel is first permitted to drop into the car direct from the two conveyors, until the two ends of the half section of the car become filled, when incline troughs (See figure) are set to direct the material from both conveyors into the intervening space, thus loading the half section evenly over its whole length. The foreman attends to setting these incline troughs, for trimming out the load, and to shifting the cars to position in front of the machine. The loading machine is easily pushed by the shoveling crew from point to point as the bank within reach of the same becomes shoveled away. Machines of this design are used on the Duluth, South Shore & Atlantic, the Mississippi River & Bonne Terre and other roads besides the Michigan Central. An average result of a season's work (117 working days) with one of these machines in a pit at Oxford, Mich., on the Michigan Central R. R., was 240 cu. yds. of gravel loaded per day, at a cost of 5.2 cents per yard. This cost covered the expense of supplies for and repairs to the elevator, and all labor, including that for moving the tracks, the full pay of men during wet weather, when they could not work all of the time, and for time lost in standing idle waiting for cars.

Hauling Away.—The cost of hauling material from the pit is the most uncertain and the most difficult of estimation of any of the expense items connected with the work of handling material for ballasting or for filling in embankments or for other purposes. It depends somewhat upon the distance moved, but more largely upon track rights and the number of cars which can be taken out per train load, which latter, of course, depends upon the grades. The quantity of material carried per car-load is also a factor not to be overlooked, as are also any unusual difficulties in the unloading. Allowing 30 cents per day for the use of flat cars each, and 8 cents per train mile for depreciation of track, the cost of hauling material in trains of 15 cars or more, with loads averaging 8 cu. yds. per car, a distance up to 10 miles, may be taken at somewhere between 4 and 5 cents per cubic yard. Of course this estimate must be looked at in a most general way, for delay to work trains by interference from traffic, the manner of unloading, etc., all affect it. The expense for the locomotive, cars, and crew goes on just about the same whether the train is waiting or running. The average cost of hauling large quantities of gravel ballast on one of the railway systems running west from Chicago has been 0.35 cent per cu. yd. per mile. This average covers material hauled all distances up to 50 miles, on flat cars with side boards, holding 15 to 18 cu. yds. per car. The average cost of unloading with plow and cable has been 0.84 cent per cu. yd.

On roads where train movements are frequent it requires a good deal of head work to dodge the traffic trains and dispose of the material promptly and to good advantage. In this connection it is important that there should be proper switching room at the pit, else delay to the road train hauling away the material may cause the shutting down of the steam shovel or loading force. In some cases where the time for completing an important piece of work has been limited, it has been found advantageous to run the steam shovel and the work trains both night and day, in this way supplying material for a large working force during day time. If the work of hauling gravel or other material from the same pit is to continue for some time and no permanently established station is near by, it may pay to establish a temporary telegraph station at the pit, in order to facilitate the movement of the work trains.

At pits from which large quantities of material are to be taken, and particularly where more than one work train is engaged in hauling the loaded cars away, extra sidings of good length, for the use of the road work trains, are usually paying investments. They facilitate the movements of the work trains in keeping out of the way of the traffic trains without occupying the pit loading track. The use of the latter for passing purposes might in cases necessitate shutting down the shovel meanwhile. In hauling to some point where a large quantity of filling material is required, as at a long, high trestle to be filled in or large embankment to be constructed, certain economies can be put into practice which would be sources of useless expense when hauling material in small quantities to any one point. One of these is a passing siding at the trestle or embankment. This arrangement gives the work train two places for passing the traffic trains, and where the distance from pit to fill is considerable, or the traffic congested, the arrangement is sometimes a means of saving costly delays.

Cars and Unloading Plows.—In § 36, Chapter IV, in connection with the subject of ballasting new track, there are descriptions and illustrations of several kinds of center and side-dumping ballast cars. In work-train service on old track the largest practice is to unload material—either ballast or filling—from the side, and hence flat cars with plow and cable, and side-dumping cars are in largest use. An unloading plow is a heavy framework

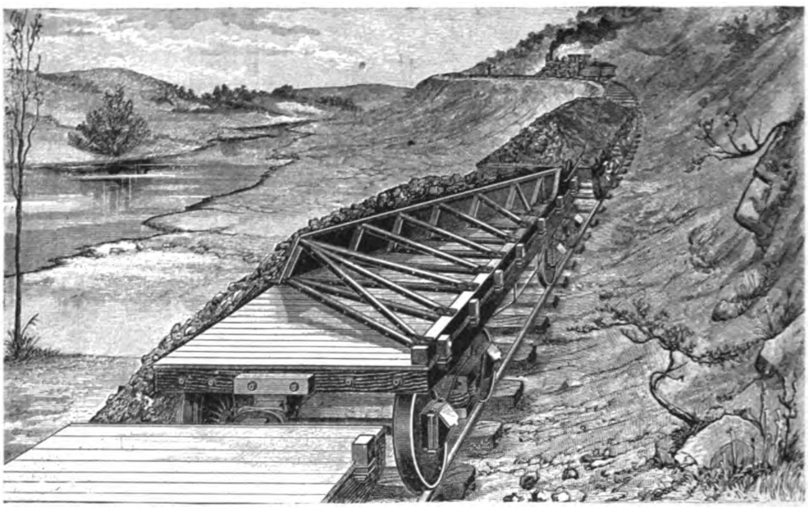


Fig. 375.—Barnhart Side Unloading Plow.

as wide as the cars, faced with a boiler-plate moldboard. The Barnhart side unloading plow, used in unloading filling material or ballast for double track and sidings, is shown in Fig. 375. Formerly the plow was guided by a timber guard bolted at one edge of the car floor and shod at the ends with beveled cast iron tips, to prevent the plow catching when passing from car to car; but as such an arrangement required some modification of the car and discommoded very much the work of unloading by hand at occasional intervals when such became necessary, such plows are now made to be guided by side stakes only. The old arrangement for guiding a plow unloading to both sides of the track was a timber guard bolted along the middle line of the car, but this arrangement also has been replaced by devices which do not require a modification of the car floor. Either type can be used on ordinary flat cars simply by taking the brake shafts from the ends of the cars and placing them at the sides thereof, and placing short stakes in the side pockets. On some roads (the Michigan Central being one) the brake shafts of flat cars used in the work train service are jointed at a socket below the level of the car floor. While the plow is being drawn over the cars the top part of the shaft is lifted out of the socket and hung on a side stake. The Barnhart center unloading plow is shown as Fig. 376. The plow is preceded by two runners or guides which bear against the side stakes and are united by an arched frame which straddles the load. The nose of the plow is hinged to the arched frame, which serves to hold it in the middle of the car. At the rear of the plow, on both sides of the car, there are trailing runners to hold the plow steady. The cable for hauling the plow is attached to the plow direct, at the nose. There is a weighted lever fulcrumed over the arch, which tends to lift the point of the plow and prevent it from scraping the car floor too hard when running in light material. The weight is adjustable and is set according to the nature of the material handled. Thus, for instance, when plowing off gravel, sand or light loam the weight is placed at the end of the lever, so as to reduce the bearing of the plow at the point and throw the weight onto the runners; but in sticky clay or soggy material, where the tendency of the plow is to lift from the car and ride the load, the weight is slipped toward the fulcrum as far as possible, so that the point of the plow may bear on the car with its full weight. In extreme cases additional weights have to be added; and this is true as to both of the extreme positions of the weight, it sometimes being necessary to place a few stones on a platform laid on the braces of the plow framing, in order to hold it down and properly clear away the material on the car. It is also customary for a man to ride the plow when difficulties of this kind are being encountered, to watch the action of the nose and lift the lever if the plow starts to ride the load. Figure 377 shows a man attending to this duty. Owing to the heavy friction against the side stakes, side plows are harder to pull than center plows.

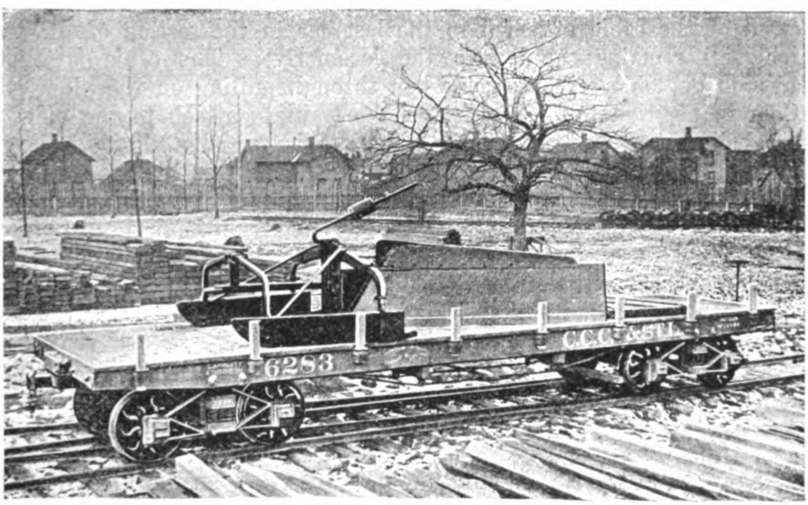


Fig. 376.—Barnhart Center Unloading Plow.

An unloading plow used on the Northern Pacific Ry., designed by Mr. H. H. Warner, master mechanic, is guided by a yoke which overreaches the sides of the car and bears against the side sills by rollers, there being no side stakes or guard timbers. This plow has a wide range of adjustment, it being possible to set it to unload all of the material at one side, half on each side, or to unload unequal parts of the material at the two sides of the car. It is illustrated in Fig. 373. The nose of the plow is adjustably attached to the guide yoke, and the spread of the latter can be adjusted to the width of the car. The rear of the plow is guided by two rollers journaled at each side, as shown, these also being adjustable to the width of the car. The guide rollers are spaced widely enough apart to straddle the opening between the cars—that is, as each pair of rollers passes the opening between the cars, the roller in the advance reaches the side of the car ahead before the following roller leaves the car behind. The plow is adapted to ordinary flat cars by placing filling blocks between the stake pockets to give an even bearing for the rollers. Cars detailed for special and continuous service in ballasting work, or for hauling material of any kind, are provided with a metallic plate attached to the side sills, as is the case with the car shown in the figure. The back ends of the moldboards project over the sides of the car, making it possible to clear the deck completely. The clevis at the point of the plow, to which the hauling cable is attached, can be moved up or down in suitable holes to adjust the draft of the plow to suit the character of the material handled. One trouble frequently experienced with unloading plows used in handling coarse material on cars with side stakes is that large stones or snags get fouled between the stakes and the plow, breaking off the stakes or wrenching off the pockets. Cakes of hardpan are particularly troublesome in this respect. It is obvious that with the Warner plow no such difficulty can arise. It is said that the plow is pulled over the cars with less than the usual amount of friction attending the operation of plows guarded by center timber or side stakes.

In usual practice the unloading plow is hauled by a locomotive, attaching to it with a 1¼ or 1½-in. wire cable reaching over the entire train to the plow on the rear car. In case the train should be longer than the cable, the train can be parted at a suitable distance from the plow and the end of the cable attached to the last car in the section of the train which still remains coupled to the locomotive. The cable is usually thrown to one side of the track when through pulling on the plow, as it is then in position to be thrown on the train to attach to the plow for hauling off the next train load. This is a better plan than to leave it lying on the empties to be covered up when the cars are loaded, for it requires considerable power to haul it through the material. Whenever it becomes necessary to load the cable, it is easier to haul the cars alongside of it and throw it on than to have the men drag it endwise over the cars. The plow is usually left on the last car to which it is hauled in unloading the train, and switched each time to the far end of the train from the locomotive. If it is desired to unload all the material in one place, as at a washout, a sink hole or at some particular point in filling in a trestle, the plow is headed from the locomotive and the cars are then unloaded by anchoring the cable to the rail at the far end and pulling the train from under the plow. In unloading by plow around a curve, the cable may be kept along the line of the cars by snatch blocks held by chains secured to the stake pockets or, better, to the track rail underneath.

By the method of hauling the plow with a locomotive it is necessary that all the material loaded upon a car be unloaded in one place, or in a distance corresponding to the length of the car. In unloading filling material or in unloading ballast for the first time along new track, where all the material is needed, this method may do quite well, providing the locomotive is heavy enough to pull the plow; but when it comes to unloading ballast the second time in one place, or wherever a smaller quantity than a full car-load is needed each car length, this plan of work is somewhat inconvenient. In some instances where the material is desired in small quantities the cars are unloaded by hand, and in other instances the cars are loaded below their capacity, in order that the plow may be used, but either plan increases the expense of handling the material. By the use of a machine with a winding drum, known as the Lidgerwood "unloader," the objections met with in pulling the plow with a locomotive are not found. This device consists of a heavy hoisting engine set up on a flat car, taking steam either by flexible pipe connection with the locomotive or from a boiler carried on the car. On some roads the outfit is called a "mill car." With this device the movement of the plow is independent of the movement of the train or of the locomotive, so that it can be hauled over the cars while they are in motion, making it possible to distribute material along the track in any desired quantities, regulated by the speed of both train and plow. If desirable to skip a place, it is only necessary to stop the winding drum until the train moves to the point where material is needed again. By hauling the plow in the same direction that the train is moving the material may be distributed in smaller quantity than the loading, and by hauling the train and plow in opposite directions simultaneously the load may be deposited along a stretch of track shorter than the length of the train; if the two are moved in opposite directions at the same speed the material will all be discharged in one place, as is sometimes desirable at a washout or in filling in a trestle. Thus, where this device is used the cars may be loaded without regard to the quantity of material that it is desired to unload per unit length of track. As an illustration of this principle, a certain railway, in handling material for reballasting, uses cars with high side boards, loaded to full capacity, and by means of a Lidgerwood unloader the gravel is deposited along a stretch of track three times as long as the train.

There are also other advantages. The plow can be pulled at a steadier speed than when hauled by a locomotive, and no brakes need be set when unloading the train at a standstill; but when hauling with a locomotive, brakes must be set to keep the cars from being started as the plow is hauled over them. The machine also has greater hauling capacity than locomotives of ordinary weight, which are sometimes unable to plow off heavy material, like sticky clay, if the cars are loaded to their capacity. In heavy pulling the locomotive is sometimes unable to start the plow without backing up and jerking on the cable, and such performances frequently result in broken cables. For this reason it is sometimes the practice to use two locomotives, in order to get sufficient pulling force to haul the plow steadily and avoid broken cables and the troublesome delays incident thereto. The capacity for hauling the plow may also limit the train-load or the number of car-loads handled in each train, for the longer the train the harder the cable pulls. In general practice it is considered that 20 car-loads are all that it is economical to handle at one time when pulling the plow with a locomotive, but with an unloading machine the plow can be pulled through as many car-loads as the locomotive can haul—35 or 40 or more cars, if the grades are not too steep. When the pulling is done with a Lidgerwood machine a man usually rides the plow and gives hand signals to the engineer of the winding engine which enable the latter to regulate the speed in accordance with the conditions of the unloading.

The cable may be unwound by making the end of it fast to a post or some other anchorage at the side of the track and then pulling ahead with the train. When drawn out in this manner it must afterward be thrown upon the cars. In order to drop the cable upon the cars as it is unwound it is usually the practice to set up a "stretcher boom" over the siding on which the loaded train stops to await orders. This is a simple and cheap device consisting of a stout pole or mast set at the side of the track, to support a horizontal arm or "boom" extending over the track at a hight sufficient to clear all cars. As shown in Sketch C, Fig. 370A, the mast is guyed, and the boom is stayed to the top of the mast and guyed to withstand the pull of the unloading cable. After hooking the cable to the boom the train is pulled slowly ahead, the cable unwinding and dropping on the center of the loaded cars. When the plow car reaches the "stretcher" the train is stopped and the cable is hooked to the plow. Another way to arrange for unwinding the cable is to drive a pile on each side of the track. When it is desired to draw out the cable a chain is stretched between these piles to clear the track about 14 ft. The cable is then hooked to the chain and as the train pulls ahead it drops upon the center of the loaded cars. Still another arrangement that has been used is an A-frame erected on each side of the track, using old bridge timber. As constructed on the Atchison, Topeka & Santa Fe Ry., this device consists of vertical posts footing between a pair of long switch ties laid to project from both sides of the track, with leaning posts to brace the vertical ones in the direction in which the cable is to be pulled out. To anchor the cable for unwinding, a chain is stretched between the A-frames

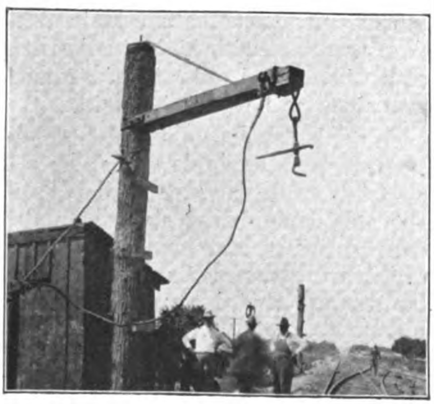


Fig. 376 A.—Cable Stretcher, G. T. W. Ry. Fig. 376 B.—Apron for Trestle Filling.

and the cable is hooked to it. When the work is completed these upright frames and track sills are taken down and out, and if needed elsewhere are set up again. A cable-stretching device that has been used on the Grand Trunk Western Ry. consists of a pile and swinging arm (Fig. 376A), the top of the pile standing 15 ft. and the arm 9 ft., above the rail. The cable to be pulled out is attached to a hook with a tripping arrangement which the brakeman (who rides the car on which the plow is carried) strikes with a stick as he passes underneath it, causing the cable to let go without stopping the train. The stretcher post or pile is driven to lean slightly away from the track, and the guy for the stretcher arm is clamped to the cable which guys the post, as shown. As the cable lets go, the spring in the guys, due to the sudden release from tension, pulls the arm back, causing it to automatically swing around clear of the track.

In order to reduce the cost of hauling material to a low figure, especially when hauling a long distance, it is necessary to send the cars out well loaded, and in this connection 25 to 30 cu. yds. should be considered only ordinary car-loads. There is no economy in handling cars loaded to only half or two thirds of their capacity. Not more than 8 or 9 cu.

yds. of gravel can be placed upon a 33x9-ft. flat car by steam-shovel loading, without boarding up the sides, for the reason that in dropping from the dipper the material sprawls out over the car; and consequently more cars are required for handling the same amount of material than is the case where it is loaded by hand, and the dead weight load runs up rapidly. Side boards at least 12 ins. high are now commonly used in loading flat cars, and in order to have them always with the car they are sometimes attached to the side sills with pieces of chain just long enough to permit them to drop down and hang about 18 ins. from the ground while the car is being unloaded. To facilitate handling these planks, a hand hole may be cut under the top edge near each end.

To increase the loading of flat cars beyond the capacity with side boards, it is now extensively the practice to side them up with outswinging doors hinged at the top and locked in position by catches at the bottom. Such is known as the Haskell & Barker type of construction. The plow being the same width as the cars inside, the doors are swung open by the crowding of the material against them, and the car is completely cleaned. To prevent material from dropping upon the track an apron of

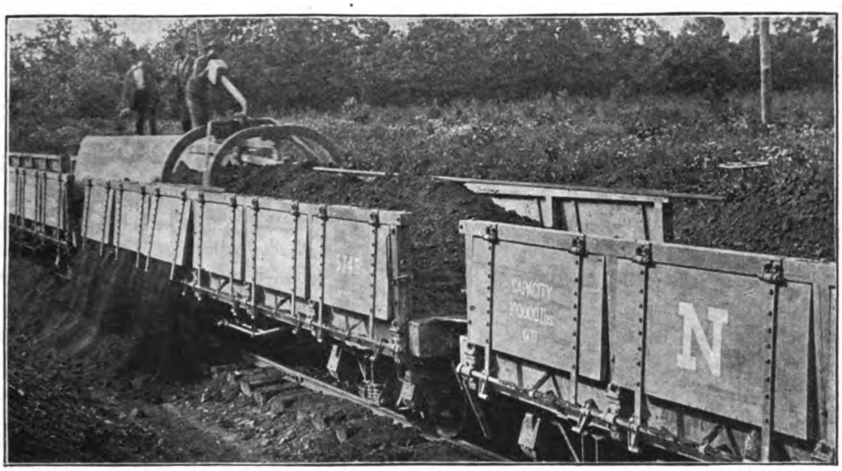


Fig. 377.—Haskell & Barker Cars, Norfolk & Western Ry.

boiler plate is hinged at one end of each car, so as to overlap the space at the coupling. A typical car of this class is the standard ballast car of the Wisconsin Central Ry. The car, which is 40 ft. long over end sills, is made by side-staking a flat car and mortising a 5x6-in. top plate over the side stakes, which are spaced 6 ft. 3¾ ins. center to center. The side doors are 2 ft. 8 ins. high, from the floor to the under side of the plate, and the top plate is 6 ft. 8 ins. high above top of rail. The side doors are hinged to the top plate with strap hinges which extend below the door and rest against the face of the side sill. Running along each side of the car there is a shaft with locking dogs which engage the bottom ends of the straps. This shaft is operated by a lever at one end of the car. There are no end boards, and at each end of the car there is a hinged apron plate of $^3/_{16}$-in. iron, which is folded across to cover the gap between the cars. The cars are unloaded by plow and cable. After turning the shaft to unlock the straps holding the side doors in place, the plow is hauled along and the pressure of the ballast forces open the doors, which return to the closed position after the plow has passed. These cars have a capacity of 100,000 lbs. and in ordinary service are loaded with about 32 cu. yds. of gravel. When the cars are not used in work-train service they are fitted with portable ends and converted into 40-ft. gondola cars for the regular freight service, for handling coal, lumber, etc. The Norfolk & Western cars shown in Fig. 377 are of similar construction. The center unloading plow seen in this picture is the Marion "Class 10" pattern for heavy duty. By heaping cars of this type they may be loaded with 40 to 45 cu. yds. of material. In making extensive grade reductions on the Kansas City Southern Ry. at one time, cars of this kind were used with remarkable effect. By loading the cars to the heaped capacity stated the average cost of hauling (average distance not stated) and unloading for a period of five months was only 1.36 cents per cubic yard. When material is to be plowed from cars with swinging sides the catches are sometimes knocked loose by two men with spike mauls stationed on either side of the train as it is moved slowly past. As the doors are released considerable material falls from the cars, and in filling trestles it is desirable that this material should drop into the embankment. One arrangement which provides for this is a platform built on each side of the track on and near the end of the trestle, on which are stationed the men for knocking loose the catches on the side boards, so that all the earth which escapes from the cars as the doors are released will drop into the fill.

When ballast or filling dirt is carried a long distance the economy of hauling and unloading is decidedly with the plow and cable method or with side-dumping cars of large capacity. The Goodwin car (Figs. 44 and 45) is of the latter class, and has been used to considerable extent under the conditions stated. The average cost of unloading with plow and cable, including labor of handling the cable and use of equipment, is about ½ cent per cubic yard. For handling filling material on short haul, careening or tilting side-dump cars are usually more economical than flat cars unloaded with plow and cable pulled by a locomotive. This comparison may be found to hold true in hauling up to three miles, and, under some conditions, perhaps, up to five miles. The facts regarding a test of the relative serviceability of tilting side-dump cars and flat cars unloaded with plow and cable, made in connection with extensive grade-reduction work on the Chicago, Burlington & Quincy Ry., at Galva, Ill., are as follows: The material was a heavy loam, loaded by steam shovel with a dipper capacity of 1¾ cu. yds. The side-dump cars used were of the tilting type, capacity 5 cu. yds., three dippers per car-load, the pit measurement averaging 3.87 cu. yds. per car. The hauling distance from pit to fill was ¼ mile to 2 miles, and two trains, hauled by switching engines, were worked continuously day and night. The work consisted in elevating 9000 ft. of double-track main-line road a maximum of 17 ft., requiring 193,000 cu. yds. of filling material. The tracks were raised with the filling, one at a time, in lifts of 3 to 4 ft. It thus happened that much of the time the material dumped did not slide clear of the track. As soon as the bank would begin to widen from the ends of the ties, the dirt dumped from the cars would be plowed out over the slope with a spreader car, which left a shoulder level with top of rail for a distance 6 ft. out. With the dumping ground in this condition a considerable portion of the load would remain in the tilted car, making it necessary to adopt the practice of dumping half the train and then pulling ahead to let the dirt slide out of the cars, when the latter would be righted and the other half dumped in the same manner. Such were the conditions during a good deal of the time of handling upwards of 5000 train-loads. The average time consumed in dumping trains of 16 side-dump cars was 1½ minutes, and the average time required to dump the cars and get them back into position—that is, from the time the train stopped to unload until it was ready to return to the pit—was 6 minutes. The other plan tried was with trains of 10 flat cars each, with an extra locomotive to assist in hauling the side unloading plow and cable. When working on this plan it was found that about 6 minutes were consumed each trip in stretching out the cable and getting ready to haul the plow, besides considerable delay occasioned in setting brakes to hold the cars at a standstill. The average time consumed in unloading the flat cars by this method was 20 minutes, thus deciding the competition in favor of the side-dump car, without question. The dump-car trains could handle the same quantity of material as the flat-car trains in much less time and at less cost, even when the expense of the extra locomotive used to haul the plow was not considered. The reason for using the extra locomotive was to enable the power to pull the plow steadily and avoid breaking the cable, which frequently occurred from jerking when only one locomotive was used.

In constructing new road tilting side-dump cars are very extensively used, as they can be readily transported ahead of the track-laying, and, on short haul, can be worked to good advantage by horses. For such service they are usually built for narrow-gage track (2 or 3 ft.) and are of small capacity—1 to 3 cu. yds. In widening out embankments for a second track, where the material is taken from an adjacent cut, this type of car is quite convenient and extensively used, being sometimes pulled by horses, and sometimes by light locomotives, in trains of considerable length. An interesting track arrangement sometimes employed in such places until the embankment becomes well widened out, is to use one main-track rail for one side of the tram track, the outside tram rail being laid as a third rail at gage distance from the outside of the main rail. Where the tram track diverges to clear main track a switch point is laid against the main rail. When cars are run out to dump it is of course necessary to send out flags or manipulate distant signals.

The body of the usual form of tilting side-dump car is either hinged to a center longitudinal beam of the truck or is supported by transverse rockers which bear upon tracks suspended from the truck on hanger irons at each end. In a few instances dump cars of this type have been operated automatically by an air cylinder and piston under one side of the car body. In the case of the Thatcher automatic dump cars, used on the Canadian Pacific Ry., the air was taken from, and the operation of the car was controlled from, the locomotive through a line of hose pipe independent of the brake system. These cars were designed for dumping material from trestles, so that it would be unnecessary for men to be upon the structure while the cars were being dumped. Many attempts to operate tilting dump cars by compressed air have not, however, proved successful, and the usual method of dumping such cars has been to push the body over by hand or by prying under the rockers with bars; or to have the load overbalance, so that the body would tilt by gravity upon releasing the stay chain or prop. Owing to the character of the body supports and to the method of dumping, the capacity of such cars is necessarily limited to a small quantity—usually 3 to 5 cu. yds., or perhaps 7 cu. yds. in a few instances. For this reason they are not an economical car to use in a long haul. Neither are they suitable for unloading ballast, because on an embankment of ordinary width the material leaves the tilted car with a momentum sufficient to carry a portion of it over the shoulder and waste it down the slope. On many roads there is a good demand, however, for a side-dumping ballast car which will drop all of its load near the track, as will now be explained.

On roads where the local freight trains are not hard worked it is economical of maintenance-of-way expense to have these trains distribute the moderate quantities of material usually needed for ballast replenishment; and if the cars in which it is sent can be rapidly unloaded, a great deal of ballast can be handled in this way without seriously delaying the trains. Again, there are roads, particularly some systems with poorly constructed branch lines, where only a meager supply of ballast has been provided, or where, perhaps, the track is largely or entirely ballasted with dirt. In such cases considerable quantities of gravel or cinders may be in demand, here and there, for raising the track out of sags or for ballasting stretches of track on a plan of gradual improvement. Such work may be, and commonly is, undertaken by the regular section crews, and if the ballast can be distributed by the local freight trains the saving in expense which would otherwise be incurred for extra train service is important. In order to give entire satisfaction when handled in the local freight service, ballast cars must be designed to suit several requirements besides quick action in dumping the load. Some side-dump cars deposit the ballast too far from the track, and in the case of a narrow shoulder much of the ballast, as already stated, is lost by sliding down the embankment. Again, other cars deposit the ballast so close to the track that it obstructs the rail and must be shoveled away, at some expense for labor, not to speak of the inconvenience and the time lost to the section forces in being obliged to be on hand every time ballast is to be unloaded. Another requirement is that the cars shall be of large capacity, so that a considerable quantity of material may be handled without unduly increasing the length of the train; and still there should be such flexibility in the arrangement for unloading that the material may be discharged in quantities commensurable to the work. One respect in which some side-dumping cars of large capacity fail to meet this requirement, although quite suitable for the service in other ways, is that the whole load must be let go in one place once the doors are opened.

To cite an example of a road which has in practice a well regulated system of ballast distribution by local freight trains, reference may be made to the Michigan Central R. R. This system and the plans of cars specially designed to meet the requirements were studied out by the late Mr. A. Torrey, chief engineer, whose method of loading gravel has already been described. The plan of work is such that after the gravel is loaded upon the cars no extra expense other than that which accrues in operating the regular trains is involved in transporting the gravel and unloading it at the exact points where it is needed along the track; and the delays to the regular trains in handling this material are inconsiderable. The system was intended mainly for the branch lines of the road. The ballast cars were designed with particular reference to facility of unloading, so as to dispense with an extra crew for this purpose. The cars are 34 ft. long and the carrying capacity is 80,000 lbs. The floor of the car slopes each way from the center, at a pitch of 3 in 4. The car is divided transversely across the middle into two compartments, and each compartment is divided lengthwise into three sections, the middle section containing about half the material in each compartment. The material in each section is retained or released by doors extending the whole length of the compartment. The doors for the middle section in each compartment close against the sloping floor of the car about midway between the peak and the outer edges, and are hinged from 5½x5½-in. longitudinal timbers. The doors of the outer sections are hinged from 4½x5½-in. timbers built into the sides of the car. The sides of the car are tied together in two places in each compartment by 3½x5½-in. timbers. Each set of doors is locked by a winding shaft running the length of the car—all the inner doors by one shaft and all the outer doors by another. Each shaft carries a grooved wheel which is locked by means of a friction block set by a hand wheel and screw. The chains connecting the locking wheels and shafts with the main winding shafts running the length of the car pass through an open space 12 ins. wide separating the two compartments of the car. The doors are released by the pressure of the load as soon as the friction block is withdrawn from the grooved wheel. By the means described half of the load can be dumped at one time by releasing the outside doors, while the other half may be retained by holding the inside doors in the locked position. The car stands 8 ft. 4 ins. high above the rail, and across each end and along one side there is a foot board and hand railing. The hand wheels for locking the doors are arranged at the middle of the car, to one side, on a small stand, as shown in Figs. 367 and 374. The normal capacity of the car loaded to the top timbers from which the doors are suspended, is 20 cu. yds., or 22 cu. yds. when heaped; but by placing side boards on the car the load may be increased to 26 cu. yds. There are pockets to hold planks when it is desired to heap the load. When not

Fig. 378.—Half Unloaded. Torrey Ballast Car. Fig. 379.—Empty.

in use these side boards or planks are carried in an open space under the floor, access to the same being had through a door in each end of the car. Figure 367 is a view showing the general appearance of the car when loaded. The hight of the cars has been restricted to the limit of convenient loading by steam shovel, so that they can be utilized in any equipment for general ballasting work.

The transporting of the gravel and the work of unloading it at points along the track where it is needed, as indicated by stakes set by the section foremen, is done by the local freight trains with their regular crews. As each train of this class going in the direction in which the gravel is needed arrives at the pit it takes what loaded cars happen to be on hand and, stopping at the point where material is needed, the outer doors are released and half of the load slides down into heaps at the ends of the ties on either side of the track. The train is then pulled ahead the length of the several gravel cars, when the inner doors are let go and the remainder of the gravel is unloaded. The releasing of the doors is but the work of a moment, as the brakemen have only to run from car to car and give each hand wheel a turn. The whole operation of unloading a long string of these gravel cars, depositing half of the load at each stop and pulling up in the meantime, requires but a few minutes. Figure 378 is a view showing some of these cars coupled in with a local freight train, taken just after the outer doors had been released and half of each load deposited. Figure 379 is another view showing the same cars after they had been pulled ahead and the inner doors released. The outer doors swing inward after the gravel slides out and require no attention on the part of the train crew after the material has been unloaded, as the cars are returned to the pit with the doors unlocked. As the train proceeds the empty cars are set out at the first side-track and returned to the pit by the next local freight train going that way. By dumping half the load in a place enough gravel can be placed to raise the track 8 ins. The quantity of gravel to be unloaded at any particular point, to meet the conditions there obtaining, may be suited to the requirements by regulating the quantity loaded. For this purpose load lines for 16 and 20 cu. yds. are marked on the car. The stakes set by the foremen to indicate where ballast is needed have arms or pointers showing in which direction from the stake the ballast is to be dumped. A valuable feature of the work is that the material is deposited close to the track but not near enough to obstruct the rail, so that no attention to the unloading is required of the section men.

The Pratt side-dumping cars of the New York, New Haven & Hartford R. R., which have one swing door above another, for unloading half the material at one time, are described in connection with the work of ballasting new track (§ 36, Chap. IV). In the same place some account is also given of the method of unloading ballast between the rails from hopper-bottom gondola coal cars. This plan is sometimes followed also on old track, where the line is being reballasted or the ballast replenished, such being the case on the Norfolk & Western Ry. The practice there is to remove the old ballast filling as low as the bottoms of the ties and throw it out to widen the shoulders. The hopper doors are opened in one car at a time, and just far enough to let out the desired quantity of gravel, which is struck off level with top of rail by skidding a tie ahead of the wheels of the rear truck. If a large quantity of material is to be leveled down and spread out over the rails in this manner, two ties are used—one on top of the other. To prevent the wheels from mounting the tie that is being shoved before them, as they are liable to do in case the tie should strike a lump or other obstruction, the brake on these wheels should be set up tight.

Filling Trestles.—Improved earth-handling appliances, such as steam shovels, material cars and unloading plows of large capacity, have so cheapened the cost of handling dirt that trestle filling has become a widely established method of constructing railway embankments. When new roads are being constructed it is frequently the plan to build temporary trestles out of timber conveniently at hand, in order to quickly open the road for traffic and begin earning money, while these trestles are being filled in with steam shovels and work trains at much less cost than it could have been done by contract from borrow pits or adjacent cuts at the time the roadbed was being graded. It is also a policy, now widely adopted, to fill in all the old wooden trestles of moderate hight as fast as they require renewing. In support of this plan there are many considerations, such as the relative cost of track and bridge maintenance, danger from fire, accidents liable to happen in cases of derailment, etc. Investigations of the comparative cost of embankment filling and wooden trestle construction have shown that, under usual conditions of timber supply and traffic movement, trestles as high as 22 to 25 ft. can be filled as cheaply as they can be rebuilt, considering first cost only; and that, taking the cost of periodical rebuilding and the various items of bridge inspection and bridge maintenance into consideration, it is an economical proposition to fill trestles up to 50 ft. in hight, providing unusual difficulties are not encountered in maintaining a waterway. Local conditions, such as cost of timber and cost of handling earth, as influenced by interference with work-train service by the traffic trains, might change these figures one way or the other, but for general practice they are regarded as typical limits unless the situation is attended with exceptional conditions.

Before the work of filling a trestle is started there are two important matters requiring investigation. One of these is the area of the waterway to be left in the embankment. This question, which has a bearing on the size and design of the culvert or of the bridge construction, in case an open waterway is decided upon, is treated with some fulness under the subject "Culverts," § 5, Chap. I. The other matter, the importance of which increases with the hight of the trestle, is the character of the bottom. It is well understood, of course, that the surface is sometimes unable to support a high fill. In order to properly understand the conditions it is therefore necessary to examine the under formation. This may be done by digging pits or driving piles, at different points. Almost any kind of surface except solid rock will settle at least a little under a high fill, but excessive settlement may badly break up or wreck any culvert that is not placed on a solid foundation. Some experience is necessary to prompt the judgment in matters of this kind. The remedy for a soft or unstable bottom is to start the culvert on a pile and concrete foundation. Some attention should also be paid to the character of the material dumped. Clay is treacherous and should not be placed in any part of an embankment. Whenever it meets with water it assumes a slippery condition, and is frequently the cause of sliding embankments. Material ditched from cuts should be rejected for filling purposes if it possesses the characteristics of clay, but mud or other wet material is not necessarily objectionable.

In filling trestles it is the practice to a considerable extent to put in the base of the embankment with teams. The local conditions, such as the opportunity to use grading machines or to open borrow pits within economical distance for hauling in scrapers, may be such that a good deal of team work can be done to advantage. It may also be necessary to construct ditches for draining the ground or to change the course of a stream, and in such work teams would usually be employed and the excavated material hauled into the base of the fill. The bulk of trestle filling is, however, usually done with trains, using cars that are unloaded from the side—either flat cars with plow and cable or tilting side-dump cars.

In dumping material from high trestles considerable damage is frequently done to the bents and bracing in being struck by large stones or heavy lumps of material falling from the cars. In order to prevent trestle posts or piles from being knocked or crowded out of position while filling is being done, struts of old timber are sometimes fastened between the ends of these members, underneath the caps; and in trestle bents of two or more decks struts are placed between the posts both underneath and on top of the inter-caps. In filling very high trestles such reinforcement is not sufficient protection, and in order to avoid damage or accident in such cases it is sometimes the practice to construct an apron of heavy plank or timbers sloping outward from the top of the trestle, so as to deflect the material and cause it to drop far enough out to clear the bracing and batter posts. The apron also drops the material nearer the foot of slope, so that there is less sliding of the material in building up the embankment and less material to move in case the practice is followed of leveling down the dirt as fast as it is dumped. Figure 376B shows an apron for trestle filling in use on a structure about 100 ft. high, on the Southern Pacific Lines in Oregon. The apron was built to slope from the ends of the bridge ties and was supported upon stringers placed upon the caps of the trestle bents and on braces footing against the batter posts of the bents at the level of the bottom of the top deck. The timber used consisted of old stringers of odd sizes. The apron was taken up when the fill reached the lower edge. Owing to the cost of erecting these aprons and removing them when the embankment approaches completion, this company has abandoned the use of them on structures lower than 60 ft. in hight. In such cases it is the practice to merely strengthen the girt timbers temporarily by using old trestle stringers. In the experience with trestle filling on this road it has been observed that the girt timbers are the members which suffer most from the material dumped. Aprons are sometimes made as a screen, with plank set edgewise, to let the fine material drop through but to intercept large masses and throw them clear of the trestle bents.

In building some remarkably high embankments on the Boone cut-off of the Chicago & Northwestern Ry., between Boone and Ogden, Ia., portable aprons were used to protect the temporary trestles erected for the purpose of construction. As, however, the arrangement is applicable to old trestles as well, a description of these aprons and their operation is not out of place here. The general scheme, which was adopted with a view to spread the material over the entire width between the slope stakes as it was unloaded, was to dump it from two lines of trestle 80 ft. apart constructed across the ravine. On each side of each trestle, 10 ft. below the top, a bench or shoulder was built to support a track which carried the portable apron or chute. Half of this apron, in width, was a good deal longer than the other part, and the two parts were separated by a vertical partition. Material dumped into the longer side was dropped out near the slope stakes, while that dumped into the short side fell closer to the trestle. As the material accumulated in a place the apron would be moved along. In this way the embankment was built up by dumping the material in two parallel ridges each side each trestle, or eight ridges in all.

For temporarily supporting the track over culverts built under trestles that are to be filled in, the Atchison, Topeka & Santa Fe Ry. has made extensive use of a pair of through girders 80 ft. long. After the culvert is completed the embankment is filled in, either with wheeled scrapers or by dumping from a work train, and as soon as the track can be supported on the grade the girders are picked up by a derrick car and shipped away for use at some other point.

In filling trestles it is usual to permit the material to drop and form its own slope as the embankment is built up. Embankments built in this manner, however, are loose and will settle about 10 per cent in hight, and when thus made they are usually permitted to settle for a year or longer before the trestle floor and stringers are pulled. In this way a good deal of expense is entailed keeping the track in surface. As the embankment is formed in sloping layers it frequently happens that troublesome slides will occur, for which reasons some engineers think that it pays to level down the material as it is dumped from the cars. If such is done with teams and scrapers the embankment becomes solidly compacted and will not settle appreciably after the work is completed. It also prevents damage to the trestle and distortion of the track alignment during the progress of the filling. Where the material is dumped and allowed to take care of itself, braces are liable to be broken by the weight of the earth and trestles are frequently pushed out of line by unequal pressure of earth against the bents or unequal settlement of different parts of the embankment. A trouble that is frequently experienced is that the batter piles of pile bents and batter posts of framed bents are crowded toward the center of the bridge, causing them to drop away from the cap and leave it supported only on the plumb posts. At a high trestle the fill should be built up more or less uniformly from end to end. If the filling takes place from one end or is made too fast in one place, the pressure of the earth against the bents is liable to strain the structure longitudinally. In filling over culverts the material should be deposited directly on top or simultaneously from both sides, avoiding a slope against one side only, as unequal pressure which then exists is liable to shove the culvert or crowd in the walls. The sliding of material is sometimes caused by plowing large masses of earth down the slope, as with a side leveler, about the time the embankment is being finished out. The slipping of an embankment may also occur where loose material has been deposited on ground which slopes transversely to the track. A way of preventing this is to cut trenches parallel with the track before the filling is started.

One road whereon conditions of the foregoing description have been carefully investigated for a number of years is the Nashville, Chattanooga & St. Louis Ry. On the Paducah & Memphis division of this road a number of high trestles have been filled in at various times, and numerous interesting details of the practice of doing the work and of the behavior of the material in the embankments have been described in papers presented before the Engineering Association of the South, by Mr. I. O. Walker, assistant engineer with the road. On this road it is the practice to level down the material with teams and drag scrapers as fast as it is unloaded from the trestle. In spreading the earth the fill is kept a few feet higher in the center, so that the loaded teams can pull down hill. The outer edge of the fill is also carried about a foot higher than the adjacent material, so that in case of rain the water will soak into the fill and not wash down the slope. The fill is checked occasionally to see that the slope is being carried up correctly, and practically no trimming is done. The outer row of scraper loads is dumped about 1 ft. inside the slope line, as it is found that when the next row is dumped the teams will tramp the first row out to the slope line, thus finally getting the earth where it is required and packing it solid. The cost of spreading earth in this manner for trestles under 30 ft. in hight is about 2 cents per cu. yd. and for trestles 50 ft. in hight the cost is about 2.8 cents per cu. yd., wet weather increasing the cost in either case. When trestles have been filled in this manner the embankment is so solid that the ties and stringers are pulled within 10 to 60 days after the filling is complete.

On this road high fills receive careful attention for a year or two after completion. If holes are washed in the slopes by rain they are promptly filled with good earth, and new embankments are protected by planting Bermuda grass all over the slopes. This is done by setting tufts of grass in rows 2 ft. apart each way. In order to get the grass to take root quickly the richest earth dumped from the trains is scraped out to the slopes, and sometimes stable manure is mixed into the layers at the outside of the fill. Fertilized in this manner it usually occurs that a continuous sod will be formed all over the slopes within a year.

In filling high trestles it will frequently occur that the trestle will settle as the embankment rises, owing to the settling of the original surface from the pressure of the fill, and if the fill settles unevenly it may crowd the bents over and pull the track out of line. When such work is being done it is therefore necessary that the track should be closely watched and maintained in fair surface and line. Surfacing may be done by shimming up the stringers, but the easiest way to reline the track is to draw the spikes and set the rails over. In order to have ready access to the caps and stringers it is a good plan not to fill higher than the caps until just before the ties and stringers are to be pulled. If access to the caps is obstructed by a mass of frozen earth the difficulty and expense of reaching them when it becomes necessary to block up are considerable. It is sometimes the practice to fill in the embankment to the level of the bottoms of the ties but leaving sufficient open space at each bent to expose the cap.

When trestles are filled the usual practice is to permit the floor system to remain until the embankment has become well settled, which may take a year or longer. When finally the track is put upon the grade it is necessary to "pull" the stringers, level down the roadbed and ballast and surface the track. The easiest way to remove the stringers is to first take up the rails and ties. The work of lifting out the stringers with track jacks and bars is a "tough job," and on some roads it is done with a derrick car, using a pair of heavy tongs to grapple the timbers, so that but little or no digging is required. Such is the practice on the Nashville, Chattanooga & St. Louis Ry., where a steam derrick car with a 24-ft. boom is used to lift the stringers and swing them out of the way, the rails and ties being removed from 60-ft. sections at a time. On this road the cost of pulling long trestles has sometimes been as low as 12 cents per foot, the cost being highest for the short trestles. In one instance the cost of pulling 1144 ft. of trestle top and replacing and surfacing the track was $506, or 44.2 cents per foot.

Filling Trestles by Hydraulic Methods.—The economical and very extensive operations of moving earth in hydraulic mining suggested the application of the same process to railway trestle filling, and on the Northern Pacific and Canadian Pacific roads a large number of high wooden structures have been filled in this way. The process, commonly known as sluicing, consists in loosening the material—gravel, earth or loose rock—from the bank with a powerful hydraulic jet and conveying it to the site of the trestle in sluice boxes or flumes. The water is obtained by diverting mountain streams at a sufficiently high level to produce the pressure required for such purposes. The flow to the monitor is through strong iron pipe, the head sometimes being upwards of 200 ft. The monitor is provided with nozzles 3 to 6 ins. in diameter, according to the head and the character of the material. For breaking up masses of material the small-size nozzles are most effective, while for flushing the sluices the increased volume of water required is furnished by the larger ones. By directing the jet against the face of the hillside the earth or gravel is broken up by the force of the discharge and brought down in the flow to the sluiceway. The sluice box or flume, which is sometimes 3 ft. wide and 3 ft. deep, is laid to a steep grade—10 to 25 per cent—so that heavy material, including boulders as large as 18 ins. in diameter, is readily carried with the current. To protect the flume from scour the bottom is paved with wood blocks or laid with old rails. The distribution of the material at the place of deposit is controlled by shifting the end of the flume from time to time and by deflecting the current to desired points on the fill.

As the material drops upon the fill it is carried in rivulets toward the slope, and as the water drains away the solid material is left behind.

To prevent washing where the water runs strong on the fill, boards are sometimes set down to break the force of the current and catch the material, and are then pulled up as the embankment rises. To deflect the current to desired points short pieces of plank with braces at the back are used. To protect the edges of the newly-made bank from washing down, hay, straw, marsh grass or brush is used as a binder. To confine the filling to proper limits and to form the slope to the established angle (usually about 38 deg.) old ties or logs are laid at the edge in rows, to form tiers on the slope. One advantage in binding the layers of material with hay or straw is that the seeds will germinate and soon grow a sod. The retaining logs are sometimes selected from wood that will take root and sprout, and thus in a short time bind the surface mass firmly together. The levee at the outside of the fill is carried up and maintained several inches to a foot higher than the interior, so as to form a pool and cause the water to drop its sediment before escaping.

Filling by the sluicing process has been done at the rate of 500 to 1500 cu. yds. of embankment built per day, using one nozzle. The quantity and the cost would, of course, be expected to vary with the character of the material, the water supply and other local conditions. The labor required is five to nine men with each nozzle, including one expert to handle the nozzle, two or more men with hooks to keep the sluices clear and two to six men to take care of the material on the embankment. The cost of the work has been 5 to 8 cents per cu. yd. The average cost of several million cu. yds. of hydraulic filling for the Northern Pacific Ry. was about 6 cents per cu. yd. In one instance where the sluiced material was conveyed a distance of ½ mile from borrow pit to fill the cost was 5 cents per cu. yd., including all charges. The average cost of moving 377,000 cu. yds. in filling eight trestles was 4.79 cents per cu. yd., of which 3.85 cents was the cost for sluicing and building side levees and 0.66 cent the cost for lumber and labor in building flumes. The remainder (0.28 cent) was for tools, levee material, superintendence and engineering. In one case where the water was pumped the cost of filling 42,250 cu. yds. averaged 13½ cents per cu. yd. In filling a trestle at North Bend, in the Frazer river canyon, on the Canadian Pacific Ry., the embankment built was 231 ft. in extreme hight and contained 148,000 cu. yds. The material in the pit consisted of 50 per cent cemented gravel, 30 per cent loose gravel and 20 per cent large boulders which had to be removed by a derrick. The cost for all charges, including explosives to blast the cemented gravel, averaged 7.24 cents per yard. Of this 3.44 cents was for the plant. The working force consisted of eight men, all common laborers except the pipeman. At a similar fill of 66,000 cu. yds. the total cost was 7½ cents per yard, of which 3.2 cents was for the plant and 1.78 cents the actual cost for sluicing. The embankments formed by this process are said to be very compact, insomuch that the foundations of masonry abutments and piers can be laid in the same. After completion no settlement of the material is noticeable. Aside from being cheap, the process has the further advantage that it does not require work trains or in any way interfere with the traffic of the road.

Hydraulic dredging is another process that has been employed, in cases, to fill in trestles or "make land" for railways. The opportunity to handle the material in this way has usually been in connection with harbor work. In hydraulic dredging the sand and other material at the bottom is taken up with the water by a revolving cutter and forced through a line of pipe extending from the dredging boat to the place of deposit. This pipe is supported at intervals upon scows or light pile bents. As the spoil falls from the end of the pipe line the water drains off, leaving the entrained solid matter behind. An interesting piece of work of this kind was the filling of 12,600 ft. of trestle of the South Pacific Coast Ry., extending from the mouth of Oakland harbor to the Alameda pier, in the Bay of San Francisco. This trestle, which ran parallel with the government channel into Oakland harbor, at a distance of 250 ft., was 8½ ft. high at the shore and 20 ft. high at the pier, the track being 7 ft. above mean high water and 11 ft. above mean low water. In dredging out this channel the spoil was used to fill in the whole space between the south line of the channel and the far side of the railway trestle. To retain the embankment and protect it from the waves, rock revetments were built along the boundary lines. Before the dredging began sheet piling was driven along the south side of the trestle, behind which the rock was eventually deposited, partly from barges and partly by dumping from cars on the trestle. The rock and dredgings were put in as nearly as possible at the same time, so as to keep the pressure of the dredgings on the inner side and the rock on the outer side about equal, to prevent the bulkhead giving way. At the track side of the embankment the top of fill was made level with the top of ties, but at the channel side it was made 1 ft. below the top of the training wall, which was 7 ft. below the level of the top of tie on the trestle. Thus the top of the fill has a gradual slope from the track to the channel. At the west end the embankment gradually widens from 250 ft., at a point 2100 ft. from the bay end of the trestle, to 525 ft. at the end of the embankment. This road is part of the suburban system of the Southern Pacific Co. terminating in Oakland, Cal. The dredging was done by The New York Dredging Co.

149. Wrecking.—At least some part of the work of clearing up wrecks falls to the track department, while on some roads the entire work of clearing the line for traffic and picking up the wreckage is placed in charge of the roadmaster or other track officer. In the organization of wrecking crews the most common practice seems to favor the plan of selecting the nucleus of the crew from men working around division headquarters, such as machinists and repair men from the locomotive and car shops, car inspectors, roundhouse employees and trackmen working in the yards. These men are within easy call during working hours, and their places of residence are known at the train dispatcher's office, so that at night or when off duty, they may be quickly called into service by messenger. Men who work at repairing rolling stock are familiar with the use of jacks, ropes and tackle and, having experience in placing crippled cars in running order, are usually given charge of the derrick car and jacks. The balance of the crew is usually made up of work-train hands or section men picked up by the wrecking train on its way to the scene of the wreck. As outlined thus far the organization may be considered applicable to railways generally, the respect in which custom varies with different roads being in the matter of supervision. As bosses, big and little, are nearly always on hand in good numbers at a wreck, there is never any lack of authority, and it is therefore important that an understanding be had as to who shall have the direction of affairs. Two systems are recognized: one in which the roadmaster takes charge and handles the bulk of the work with the track forces, the men from the shops then being employed as experts at stripping locomotives and looking more particularly to getting the rolling stock into running condition, so far as may be. By the other system the mechanical department is placed in authority, the master mechanic or one of his assistants being placed in charge as wreckmaster. In any case the track forces must look after placing the track in repair and all the "dirty" work, such as the handling of freight, lugging blocking, heavy tools and tackle, sinking dead men, etc. It would hardly be possible to clear away a bad wreck in good season without the aid of the track department.

The plan of placing the track department in full charge of the wrecking operations is perhaps more usually the case on roads where a work train is constantly employed. Under this arrangement the foreman of the work train usually takes charge until the roadmaster arrives. The work-train crew is more at home out on the road in all kinds of weather than are machinists and other workmen from the shops, and work-train crews of the old class soon become expert at handling heavy masses. Some of the work-train crews employed these days, however, would make but little headway at picking up wrecks—not even with the aid of a half dozen interpreters. The work of wrecking should never be incumbered by a confusion of tongues. Such labor can dig sewers and shovel ballast, but it cannot handle a wreck to any advantage. This much said in a general way, it may be well to mention various plans of organization for clearing wrecks, as carried out on a few of the principal roads of the country.

On the Southern Pacific road each division is provided with an outfit consisting of a derrick car, two tool cars and one camp or cooking car. This outfit is held at division headquarters in charge of the master car repairer, who has charge of handling all wrecks. The master mechanic also accompanies the outfit train when it becomes necessary to handle a wrecked engine. This outfit, with 10 or 12 men from the shops, is run special to the wreck as soon as it is reported, and additional force is picked up from the section gangs. There is also a telegraph outfit which is taken along and cut in, if the wreck is a bad one. It is frequently the case that two outfits are sent to one wreck; that is, should a serious wreck (one requiring some hours to clear) occur as much as 100 miles west of El Paso, one wrecking outfit is dispatched from Tucson and another from El Paso (312 miles east of Tucson), one outfit working at each end of the wreck.

On the Nebraska division of the Union Pacific R. R. there is, on the main line, one complete wrecking outfit stationed at Council Bluffs and a smaller one at North Platte. The outfit at Council Bluffs is equipped for the heaviest kind of work and has a regular force of one foreman and one assistant. When the outfit is idle it is taken care of by these two men; when in service, the extra force necessary is drawn from the shops and section gangs. Usually the same shop and track men are selected, on account of their familiarity with the work of handling wrecks. In extraordinary cases a large number of men are drawn, usually from the track forces. The outfit at North Platte is for lighter work and its working force generally consists of a few men taken from the shop at North Platte and from track men collected at the scene of the wreck. On the Wyoming division of the road there is a steam derrick car kept in readiness at the middle of the division, to facilitate getting it to any point quickly, and arrangements are made whereby an experienced wrecker is always with it. One man is sent along to look after tools, and three car repairers and six handy men accompany the car regularly. Extra men are drawn from the section crews. At district terminals there are hand derrick cars, with a regular force of car repairers who go out whenever it becomes necessary to pick up a pair of trucks or a small wreck. By a system of signals for calling out the men it is the aim to get started within 30 minutes after the wreck is reported.

On the Great Northern Ry. there is at most division points a regularly organized force consisting of a car foreman and several car repairers or rough carpenters—men who are handy with jacks and other tools—who are called upon for wrecking service. The balance of the force is drawn from the track. On the East Iowa division of the Chicago, Burlington & Quincy Ry. the wrecking crew is composed of round-house men and laborers. If the wreck is of considerable magnitude any force of men additional, track men, bridge men or other available help, is called upon. After the track is clear a force is selected to work with the wrecking outfit at picking up the wrecked cars. On the Atchison, Topeka & Santa Fe Ry. the wrecking crews work at track repairs at the division points where the wrecking cars are located. The number of men sent out is determined by the seriousness of the wreck and the damage done. If an engine is wrecked a machinist and helper from the shops are sent, but usually the car repairers, with their foreman, constitute the skilled labor of the crew. The roadmaster always goes to the wrecks and generally takes charge, unless the trainmaster or superintendent is present. On the Illinois Central R. R. the regularly organized wrecking crew consists of a foreman and six men, who take charge of the wrecking outfit. All of these men are employed in the car department at district terminals. Where engines are damaged and it is necessary to strip them a machinist is sent. The six regular men are used as follows: one man on the deck of the derrick car, one to each guy, one giving signals, one to make hitches and one attending to the line. The six men are used first in preparing each portion of the wreckage for the derrick, such as disconnecting brake rigging, taking out trucks, etc. In addition to this force a sufficient number of track laborers, with their foremen, are called to the place of the accident to transfer freight and assist the crew employed on the derrick car, the number of men so furnished depending upon the condition of the wreck.

Of roads entering Chicago the one best equipped for handling wrecks is probably the Chicago & Western Indiana R. R. This company has two large steam wrecking cars, one of 35 tons' capacity (Fig. 396) and the other of 45 tons (Fig. 395), and this outfit is available for any road entering the city of Chicago, whenever the wreck interferes with the traffic of the C. & W. I. road. These derrick cars in cold weather are fired up both night and day, in order to keep them from freezing and have them ready at a moment's notice; and locomotives with steam up are at all times available. The wrecking crew is composed principally of car repairers, the car foreman being foreman of the wrecking outfit. In day time the wrecking outfit can be got ready to move on 10 minutes' notice, but at night a somewhat longer time is consumed in calling the crew and getting it together. Besides the car repairmen noted there are two machinists—one running the engine and the other working the crane—who go with this wrecking outfit. As a matter of record, this crew in one year picked up 66 locomotives and 523 cars. Most of these wrecks interfered with the traffic on the C. & W. I. tracks, but whether the wrecks occur to the company's own trains or to foreign trains the outfit is sent immediately to the wreck to pick it up, and the bill for the work is sent the company responsible for the damage.

On the Allegheny division of the Erie R. R. the wrecking crew is organized from the shop forces under a wreckmaster. These men are generally engaged in doing labor around the shops, such as loading and unloading materials, handling scrap, etc., but with them are sent a sufficient number of skilled men from the repair yard. This force at the terminals is organized into gangs of four men each. When a derailment occurs the shop is immediately notified and advised as to about how many men are necessary. Callers are immediately given slips on which are shown the date, name of caller, time he receives the slip and the names of the men to be called, who live in the vicinity of the shops. This slip the caller returns to the shop with a record of the time each man was called. This system gives better satisfaction than the old way of calling the wrecking gang by whistle or bell, as the location of the men about the shops is known during daytime and they are expected to be at their homes at night. At the same time the shop is notified the yardmaster is notified, who calls the first crew ready to run the wrecking train. It is not found necessary to hold a crew (train crew) specially assigned to the wrecking train in readiness, as the time consumed in getting the wrecking train out of either terminal of this division averages only about 40 minutes, which includes the time required in securing orders, etc. A track force in sufficient number to repair the track and do the rough work of wrecking is notified and picked up en route. In every case of derailment where the wrecking crew is ordered the track supervisor on whose subdivision the derailment occurs goes on the train; also the division roadmaster, who looks after the general disposition of the track forces, and attends to the care of the merchandise, etc. The trainmaster also accompanies the wrecking train to attend to and care for the matters of transportation in connection with the derailed train and to order the movement of traffic at the wreck. The wreckmaster has entire charge of the wrecking forces and the clearing of the road, but the roadmaster and trainmaster, in their respective departments, are supposed to give him advice and assistance. The trainmaster is in authority and represents the superintendent in case he is not at the wreck.

On the Lehigh Valley R. R. the wrecking crews are made up of shop men in charge of one of the car shop foremen. On the Western division of the Fitchburg R. R. the wrecking operations are under the direction of the roadmaster, who mans the force from the work-train crew. In case an engine is in the wreck the machine shop is called upon for machinists to accompany the crew. On the Atlantic Coast Line the shops are drawn upon for forces to handle the derrick and jacks. A representative of the track department accompanies the train and furnishes any additional labor that may be necessary. On the Pennsylvania R. R. wrecks are handled by the division work trains, the work-train foreman or supervisor being in charge of all the details of the wrecking operations. On the New York, New Haven & Hartford R. R. the wrecking crew ordinarily consists of 15 or 18 men taken from the locomotive and car shops, the foreman being one of the erecting foremen in the locomotive machine shops. This crew is increased, when necessary, by details from the regular track force, to do the rough work. The train, including a steam derrick car, a car loaded with trucks, a car loaded with blocking, tool car and locomotive, is always kept in readiness on a side-track. One of the spare engines from the roundhouse is run out to the train and stands on side-track instead of in the house until it goes out on its next run, when its place on side-track is taken by another locomotive. The engine number is always known by the dispatcher, which arrangement avoids delay in getting the train orders ready, and during working hours the train is frequently off within two or three minutes after receipt of the notice of a wreck. Steam is kept up in the boiler of the derrick car, the fire being looked after by the roundhouse men. The signals for calling the men to the train are given by air whistle in the shops and by a large bell rung by compressed air in the roundhouse, both being operated by the telegraph operator in the master mechanic's office. When these signals are sounded throughout the works the members of the crew are supposed to drop everything and make for the train on the run. The total cost of maintaining the equipment in readiness to start is $3.15 per day. This estimate does not include a charge for the locomotive, because one is selected which would ordinarily stand in the house, so that no locomotive is kept out of service on this account. The system of keeping a locomotive standing coupled to the train with steam up is also in practice on other roads.

Wrecking Tools.—The first thing to look to by way of preparation for such sudden emergencies as train wrecks is a sufficient supply of efficient tools. The list of tools needed is a long one. They may not all be serviceable at any one time, but will always be appreciated when they are needed. It is altogether probable that no road, or but few roads, at the most, would use a selection of tools as large as that in the following list. The intention is to present a list that includes typical selections of the various kinds of tools, most, if not all, of which are in use on a considerable number of roads. In the line of jacks the usual selection is four 30-ton and two 20-ton hydraulic jacks, both crown and toe lift; two 8-in., two 12-in., four 18-in and four 24-in. screw jacks; a pair of Pearson jacks. Hydraulic jacks of 10 or 15 tons' capacity are frequently included, but four 10-ton ratchet track jacks may be substituted for the light lifting.

In looking over the wrecking outfits of half a dozen different roads picked at random it is seldom that the ropes of corresponding diameter will be found of the same length, or even approximately so. Rope 3-ins. in diameter is the largest in general service, one or more pieces of good length being usually furnished for heavy pulling through snatch blocks, although rope of this size is sometimes carried in pieces as long as 600 ft. or longer for block and tackle work. For heavy block and tackle work 2½-in. rope is generally standard, being used in lengths of 800 to 1500 ft. For lighter work of this kind 2-in., 1¾-in. and 1½-in. ropes are used, all three sizes being frequently found in the same outfit. For hand lines 1-in. rope is preferable to 1¼-in. or ¾-in. sizes, for general service, although all these sizes are sometimes found in the same outfit. Switch ropes of 5 ins. diameter are sometimes carried, but wire rope of equivalent strength is to be preferred. The following might be taken as a fairly representative equipment of wrecking ropes, specifications usually calling for No. 1 manila: One piece of 3-in. rope 300 ft. long, with one double and one triple pulley block and three snatch blocks; two pieces of 3-in. rope, one 80 ft. and one 125 ft. long; one piece of 2½-in. rope 1200 ft. long, with one triple and one quadruple pulley block and three snatch blocks; one piece of 2½-in. rope 500 ft. long, with one double and one triple pulley block; one piece of 1¾-in. rope 500 ft. long and another piece 300 ft. long, with two double and two triple pulley blocks and three snatch blocks; one piece of 1-in. rope 500 ft. long, one piece 300 ft. long, one piece 175 ft. long and one piece 100 ft. long, with two double and two triple pulley blocks and three snatch blocks; one piece of ¾-in. rope 500 ft. long, with two single blocks and one snatch block, to be cut into lengths as needed. Four-strand rope is more evenly round than 3-strand and is preferable for use in tackle blocks. For convenience of reeving the long ropes in blocks, both ends of the same should be free, and tapered and marled, but ropes larger than 1-in. diameter and as short as 100 ft. or less may have one end spliced to a link and the other end to a hook. This arrangement is preferable to splicing on a link at both ends, as the hook can be attached to a link if the latter is needed at both ends. Iron blocks are preferable to wooden ones and, to reduce the weight of the large blocks as far as possible without sacrificing strength, they should have shackles instead of hooks.

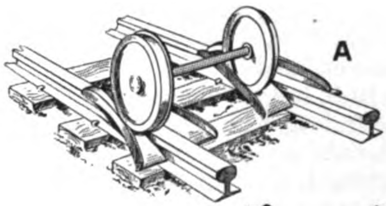
The rope list would also include about three slings of 2½-in. rope, each 12 ft. long; 4 slings of 1¾-in. rope, two 6 ft. long and two 12 ft. long; 4 slings of 1-in. rope, two 6 ft. long and two 12 ft. long; 4 slings of 1¼-in. wire rope, each 16 ft. long; four pieces of 1-in. steel wire guy line, each 175 ft. long; one 1¼-in. steel hoisting cable for switch rope, 125 ft. long, having one end spliced to a link and the other end to 10 ft. of 1-in. crane chain with hook on one end and ring on the other. The wire ropes should be spliced around a thimble at each end. There should also be a steel wire switch rope 30 ft. long, one 50 ft. long and another 80 ft. long, the ends of each spliced to hook and link. The manila switch rope will be needed where a snatch block has to be used and the steel wire ropes for straight pulling. Steel wire rope weighs only about half as much as hemp rope of equal strength, and as it does not absorb water and get soggy like hemp rope, it is better for use in wet weather.

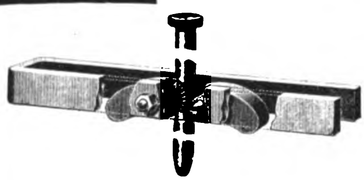
In chains there should be four best charcoal iron 1-in. crane chains, each 20 ft. long and having a 1¾-in. iron ring of 4 ins. clear diameter, on one end, and a hook on the other end; one ⅞-in. car chain 40 ft. long and six 16 ft. long, with hooks and rings; six ¾-in. log chains, each 16 ft. long, and two 10 ft. long, each having a 1½-in. iron ring of 4 ins. clear diameter, on one end and hook on the other end; six ⅝-in chains each 16 ft. long, and two 10 ft. long, with hooks and rings; one 1¼-in. chain 24 ft. long and another 16 ft. long, with ring and hook of suitable size. For hoisting purposes chain with links not to exceed ¾ in. diam. are preferable. Then what is lacking in strength of chain from links of small size can be made up by increasing the number of parts in the tackle. Hooks to hitch to the links of a chain are made diamond shape in section, with jaws open just enough to admit the link edgewise. A double hook of this kind is convenient for temporarily joining pieces of chain or for splicing broken chain. There should be clevises for all the chains; a supply of cold shuts for quickly mending broken chain, and some bulge links, part having a link attached and part without; two L-hooks for catching hold of car sills; four double or S-hooks, made of 2-in. iron, and two of 3-in. iron; six links 18 ins. to 30 ins. in length made of 1½-in. iron; four pairs of rerailing frogs; four wrecking inclines; four iron dollies, with rollers 6 ins. in diameter; eight steel rollers, each 4 ins. diameter, 15 ins. long.

Excepting hand car, push car, brush hooks, rake, grass and brush scythes and snaths, and wheelbarrows, there should be a full set of track tools, as per list given for a section crew in § 116, Chap. IX, increased by about 12 pinch bars, 3 axes, 18 shovels, 2 claw bars, 12 track chisels, 2 track wrenches, 4 spike hammers, 1 cross-cut saw, one 16-lb sledge, 6 picks, 3 peavies, 3 cant hooks, 2 kegs of track spikes, some angle bars and track bolts, 2 red and 4 white lanterns and a portable rail saw. There should be a chest of carpenter's tools commonly used in rough work, such as hand and rip saws, hammer, square, brace and full set of bits; one 2-in., one 1½-in. and one 1-in. hand auger; drawing knife, hatchet, mallet and chisel; keg of 60d wire spikes; lot of 40d, 20d, 10d, 8d and 6d wire nails.

There should be a set of machinist's hand tools, including a good assortment of monkey wrenches—say two each of 6, 8, 12, 18 and 24 ins.; also one large, one medium and one small-sized pipe wrench, and an alligator pipe wrench. There should be a set of blacksmith's hand tools, anvil, portable hand forge and fuel and a 6-in. vise. The forge and anvil can be set up on the ground beside the tool car, or on a flat car at the end of it. They are found to be very useful sometimes. There should also be included a drill press, a set of taps and dies, a few bars of round iron of different sizes, a strip of ⅜-in. iron plate and a good assortment of files. The drill press should be kept set up against a post attached to the side of the car, inside. It can easily be taken down and lag-bolted to a post or telegraph pole or other object outside the car, if there is not room to use it within.

There should be a sack of linemen's tools, including climbers; a portable telegraph set, mounted in some convenient manner; 200 ft. of flexible insulated wire; 2 coils of No. 6 galvanized iron wire; a tent and poles for telegraph office; a small "A" tent with poles, to use for a water closet, if the locality of the wreck requires it; and a railroad velocipede. And then there should be a set of car repairer's tools, with a supply of center pins, center plates, side bearings, journal bearings, a few drawheads, couplers and three-link couplings, and some extra air brake hose; a wheel gage; a quantity of ordinary sizes of bolts, short and long; a quantity of waste and car oil, packing hook and knife; a barrel of kerosene oil; one 2-gal. can of signal oil; one 2-gal. can of machine oil, and a few oilers; and perhaps several other articles which a car inspector might think necessary to have in such an emergency.





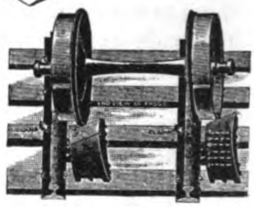


Fig. 380.—Buckeye Torch. **Fig. 381.** **Fig. 382.—Tilden Frog.**

There should be 24 oiled suits for the men to use in case of rain; and hip rubber boots for wading in water—say 6 pairs of No. 8 and 6 pairs of No. 10. A flat-bottom boat is also very useful sometimes at wrecks, and might be taken along. On some roads two or three dozen umbrellas are carried in the tool car for use in transferring passengers around a wreck in wet weather. For use in extinguishing fire there should be two empty oil barrels, 40 strong galvanized water buckets, a few lengths of 2-in. hose, with couplings and nozzle. For use in handling freight there should be 100 jute grain sacks, 20 grain baskets; a half dozen tarpaulins, 24x30 ft., for protecting freight from rain; a dozen hay-bale hooks and six pairs of ice tongs.

For work at night there should be about 20 hand torches and two pot torches. The way to place torches at desirable points around a wreck is to drive stakes into the ground and fix the torches on the stakes. Oil-spray lights, like the Wells or Buckeye portable torches, are commonly used in wrecking work at night. These torches (Fig. 380) consist of a tank, a hand pressure pump attached thereto, and a burner standing about 6 ft. high on the end of a pipe which enters the tank. The No. 3 torch has an 18x24-in. tank, holding 15 gals. of oil besides the necessary air space. The weight when empty is 110 lbs. and when full, 245 lbs. This size burns 1 gal. of kerosene per hour and produces a light of 2000 candle power. The pressure is pumped at intervals of three or four hours. The burner is first heated by burning a little oil in the pan underneath, and the light is produced by passing the oil through this heated burner, where it becomes vaporized and issues in a white, smokeless flame 30 ins. long, which is not affected by wind or rain. Two or three of these lights are usually carried in each wrecking outfit. Old locomotive headlights are also serviceable for night work at wrecks. They are used to best advantage if placed some distance away and set so as to throw the light on parts of the wreck from different directions, so that the men engaged will not have to work in their own shadow. A bonfire may also be used to good advantage for light, especially on a side hill, and in cold weather it is needed for limbering up the men's fingers, benumbed by cold. The wreckage will oftentimes supply the fuel. For lighting purposes at wrecks some roads keep on hand three or four car-loads of cord wood or rubbish cut up into cord-wood length. The lighting power of a bonfire which does not burn up quickly enough may be "assisted" by throwing on some rosin. The Pennsylvania R. R. has a car fitted up with a boiler, engine and 10-light dynamo, with a crew of four linemen to string wires and set lights for use at wrecks. The lights (arc lights) are suspended from tripods placed here and there about the wreck, and mounted on top of the car there is a search light. On a road like this, where there are four tracks on the main line, there are facilities for holding such a car at a wreck which cannot be had on single and double-track roads. It would be practicable, however, to carry a set of storage batteries ready charged for lighting purposes. These might be arranged under the derrick car or on the tool car.

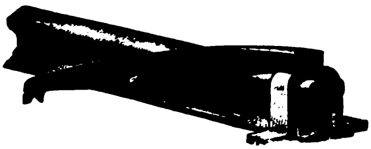


Fig. 383.—Wrecking Frog.

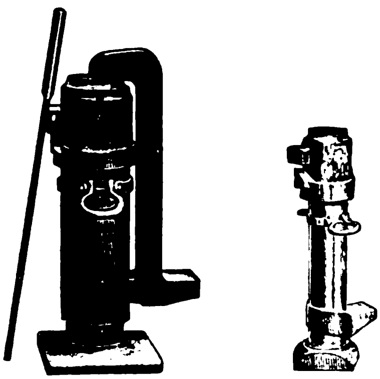


Fig. 384.—Toe-Lifting Jacks.

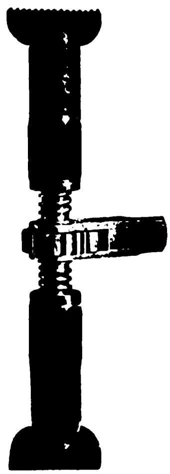


Fig. 385.—Pearson Jack.

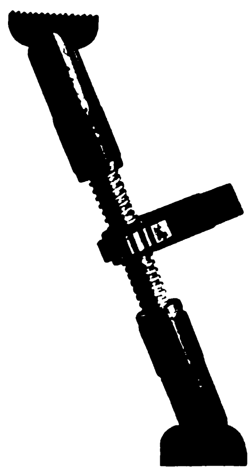


Fig. 386.

Toe lifting with hydraulic jacks, for applying the lifting force near the ground, is accomplished by either of two different arrangements, as shown on the Watson-Stillman jacks in Fig. 384. The jack shown at the right of the figure has a stationary claw cast solid with the lifting cylinder. The jack shown at the left has an independent claw, detachable from the jack, so that it need not be used when there is no toe lifting to be done. Hydraulic jacks of 20 tons' capacity weigh 200 to 225 lbs. and 30-ton jacks weigh 280 to 300 lbs. In wrecking it is frequently a matter of convenience to set jacks canting, so as to lift and carry at the same time. Ordinary jacks are not well adapted for this sort of work, since when the jack tilts over the bearing comes entirely upon one side of the base and is liable to crack or break it. The Pearson jack, shown as Figs.385 and 386, is made expressly for this kind of work. The jack is composed of five principal pieces, the central one of which is a screw, either provided with a ratchet or formed into a hexagonal nut at the middle, with holes for bars. The screw turns within threaded pieces of hollow cast iron, which are provided with swiveling foot and head, forming the bearing parts or shoes. The outer portions of the shoes are serrated for the purpose of obtaining a good hold upon blocking and car timbers. The 25-ton jack of this type weighs 85 lbs. This jack is a convenient device for placing derailed cars upon the track. Two jacks are used under the end of the car, the general arrangement being to set both jacks to lean in the direction in which the car is to be moved. If the derailed car is near the rails it is hoisted until the treads of the wheels inside the track and the flanges of the wheels outside the track just clear the rails. The truck will then adjust itself to the rails, the flanges of the wheels inside the track preventing

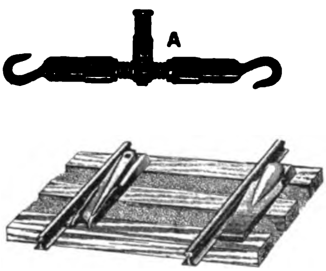


Fig. 387.—Snow Wrecking Frogs.

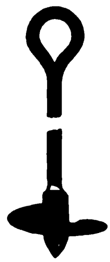


Fig. 387 B.

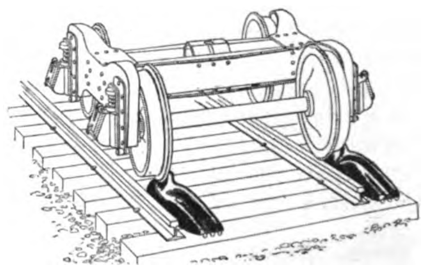


Fig. 388.—Alexander Wrecking Frog.

the truck from swinging over too far. If the derailed car is some distance from the track it is replaced by jacking one end at a time, shifting the car sidewise by swinging first one end and then the other over toward the track. In order to have the truck lift with the car it is necessary to secure it in some way to the car body. One way to do this is to chain it fast, either by taking up on the safety chains or by passing a chain over the top of the car or through the car floor. For passenger cars the practice of cutting through the car floor is, of course, objectionable. A device which obviates the use of chains is the Pearson king-bolt clamp (Fig. 381). It consists essentially of a strong bar bent double, to hold two pawls or knuckles for engaging the king-bolt under the truck bolster. As the car body is lifted the clamp holds fast to the king-bolt and the truck is lifted with the car, and, if necessary, may be swung around to its proper position on the track. Engraving *A*, over Fig. 387, shows the Pearson ratchet pulling jack, which is used where a short and powerful pull is required, as in bringing joints and connections together.

A wrecking frog is an incline of some sort for carrying a derailed wheel to the level of the top of the rail, at the same time shifting it laterally to take position on the rail. There are numerous forms of wrecking frogs, "rerailing frogs" or "car replacers," as they are variously called, and several of them are patented. About the oldest pattern, and one that is very commonly used, is illustrated as Fig. 383. It consists of a heavy bar pivoted at one end to an inverted, flanged U-strap which straddles the rail and holds the bar in position for leading the wheel onto the rail. The free end is formed into a claw for fastening to a tie. The device is used in pairs—one for each rail—and in light work gives fairly good service, but under heavy locomotives or heavily loaded cars the incline bar will bend and fail to do its work satisfactorily. Among the best known wrecking frogs or replacers are the Alexander, the Snow and the Tilden. The Alexander replacer (Fig. 388) is made of pressed steel ½ in. thick. The weight per pair is 140 to 150 lbs., the latter corresponding to rails higher than 5⅛ ins. The higher replacer of the pair is placed on the outside of the rail, and as the wheel that is derailed inside the track is lifted to top of rail the outside replacer lifts the flange of its wheel over the rail. The Snow replacers (Fig. 387) consist of a pair of inclines of dissimilar design. The inside replacer has a switch tongue which enables it to be used either right or left. At the top end of the incline on the outside replacer there is an elongated cone which crowds the wheel far enough laterally to carry its flange over the rail. On both these replacers the wheels bear on the treads, thus obviating any danger of breaking the flanges. The replacers may be laid at an angle with the rails, and when the wheels are off the ties, leads of rails can be used to carry the wheels to the replacers. As the maximum hight of the replacers is at the end, the incline is gradual, so that a locomotive can pull herself up without assistance. These replacers are made in varying weights, of cast steel for steam roads and of mallea-

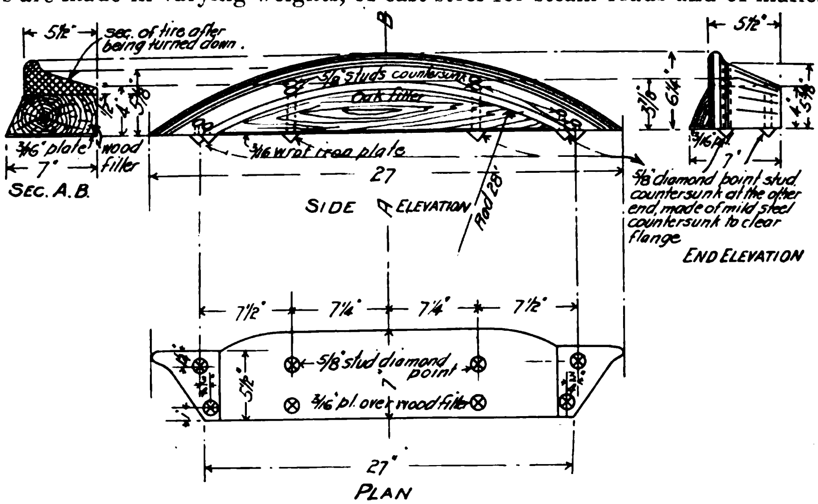


Fig. 389.—The Burlington Replacer.

ble iron for logging and electric roads. The Tilden replacer (Fig. 382) consists of a pair of segmental castings with the tops inclining transversely, so that when the wheels are lifted up they slide onto the rails. To hold the frog to its place there is a clamp fitting to the base of the rail. The Johnson wrecking frog (Engraving *A*, over Fig. 382) consists of an incline casting which straddles the rail, with ribs at the edges to guide the wheel toward the rail. In rerailing wheels a pair of frogs is used, as shown in the illustration. An obvious advantage with this frog is that it cannot slip out from under the wheel when the load comes on. The standard rerailing device of the Chicago, Burlington & Quincy Ry. is made from a segment of an old locomotive driving wheel tire, in its natural shape, with the tread beveled and the flange somewhat turned down, as shown in Fig. 389. This piece of tire is filled on the concave side with oak wood protected on the bottom by a piece of scrap tank iron, fastened with ⅝-in. steel rivets with countersunk heads and diamond points projecting ¾ in. as spurs to prevent slipping on the ties. It is made in two sizes, the smaller being 27 ins. and the larger 32 ins. in length. It was designed by Mr.

Henry Miller, while asst. superintendent of the St. Louis, Keokuk & Northwestern R. R. Heavy oak wedges about 3 to 4 ft. in length, faced with iron plates, commonly known as "wrecking inclines," are useful in lifting derailed wheels to the top of the rail, and should be included in the wrecking outfit. The bottom plate has spurs to prevent sliding on the ties.

All these tools should be stamped "Tool Car" and have besides some distinguishing mark easily seen. It is usual to paint part of the tool or its handle green or red. A skid is a useful thing to have for unloading heavy tools from the car, and it also comes handy in handling freight. The heaviest tools should be placed near the floor of the car, so as to avoid making it top-heavy. Hydraulic jacks should be kept standing upright. Such an outfit constitutes quite a little shop on wheels, but all these tools can be made use of, and besides the tool car is often needed at work other than wrecks. There are other tools which might be needed in case of a washout or bridge wreck, but most roads having numerous bridges have pile drivers and special cars fitted out with tools and appliances for bridge work.

It is money well invested to equip the traffic trains with a few wrecking appliances, as then in many cases of derailment they can help themselves and thus avoid the delay of waiting for a wreck train. Each engine should carry a pair of rerailing frogs and a pair of heavy screw jacks. Each freight caboose should carry a pair of rerailing frogs, a pair of journal jacks, a pair of 20-in. screw jacks, a pair of Pearson jacks, with king-bolt clamp; a ratchet track jack, a 3-in. switch rope 30-ft. long, with hook and link and snatch block; two $\frac{7}{8}$-in. wrecking chains, each 16 ft. long, with ring and hook; a 16-lb. sledge hammer, a machinist's hand hammer, two heavy cold chisels, a hand punch, an 18-in. monkey wrench, hand saw, pinch bar, claw bar, ax, spike hammer, two track chisels with handles, track wrench, two pairs of splices, some track spikes and bolts, some wire spikes and nails, a track shovel; a few pieces of 4x12-in. and 4x6-in. blocking, 30 ins. long, and a few pieces 2x8 ins. x18 ins. long. The heavy and bulky tools may be carried in a cellar suspended underneath the caboose.

One of the most important items of a wrecking outfit is the blocking. It may sometimes happen that but little blocking is needed at a wreck, but when it is needed in quantity it will usually be hard to find if it is not included in the regular list of wrecking appliances. Some blocking is always needed for jack footings, while on rough ground it is needed for cribbing and in soft places it comes handy for corduroying or for packing between ties. The best blocking for general purposes is sound white pine, since it is strong and light to handle, but old car and bridge timbers answer the purpose very well, and are extensively used. It is a wise provision to carry plenty of it; say 40 pieces 6x8 ins. x8 ft., 40 pieces 6x8 ins. x4 ft., 40 pieces 4x6 ins. x3 ft., 40 pieces 4x12x30 ins., 24 pieces 3x12 ins. x2 ft., 24 pieces 2x6 ins. x 2 ft., 24 pieces 1x6 ins. x2 ft., 20 oak wedges, 1x6x12 ins., and twenty 2x12x18 ins.; 1 bundle of shingles. The 6x8-in. pieces may be sawed track ties, of any light wood. There ought also to be two pieces of pine, 8x14 ins. x 15 ft., to be used as bolsters in jacking up car bodies; and 6 pieces of 7x16 ins. x3 ft. pine, or 6x14 ins. x3 ft., oak, to be used as rests for the heavy jacks. This blocking is most conveniently accessible if carried on a flat car provided with suspended side planks for steps, and with 2x2-in. strips spiked or bolted at the outside edge of the floor for grab-pieces. The blocking may be stacked up at one end, between side boards. On this car it is also well to carry six 30-ft. rails; 2 pieces of rail 12 ft. long and 4 pieces 16 to 20 ft. long, for skids;

a standard rigid frog, a set of switch points, and a ground-lever switch stand. For various purposes there might also be carried on this car several pieces each of 2x12 ins. x24 ft., 1x12 ins. x16 ft., 1x6 ins. x16 ft., 2x4 ins. x16 ft., rough lumber. On this car or on top of the tool car there should be carried a strong ladder, 30 ft long, and four short ladders which can be joined together with it. On bridge repair cars and painters' cars a long box is sometimes arranged on the roof for carrying the ladders. It is also a good plan to carry a gang plank and a runway, for transferring freight.

The wrecking outfit of the Northern Pacific Ry., at Tacoma, Wash., includes a double-deck car, designed by Mr. H. H. Warner, superintendent of shops, for carrying equipment which cannot conveniently be stored in an enclosed car, such as car trucks, rails, timbers, blocking, etc. As shown in Fig. 389 A, there is a flat car, with side stakes 8 or 9 ft. long well braced longitudinally. These stakes support the upper deck, which is about 62 ins. clear of the car floor. Of this space 40 ins. is set apart for car trucks and wheels, and 22 ins. immediately under the upper deck is used for storing long bridge timbers, etc., on rods through the stakes. Except for the stakes, the sides of the lower deck are open, but the upper deck is sided up. The lower deck is designed to carry three pairs of trucks and a pair of mounted

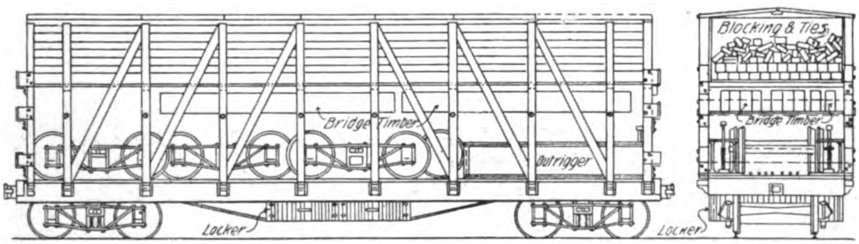


Fig. 389A—Wrecking Supply Car, Northern Pacific Ry.

wheels, on one end of the car, with the derrick car outrigging, rails, wheel skids, track levers, etc., in the center of the floor and at the sides of the trucks. The upper deck carries ties, assorted blocking, etc. Under the car there is a locker for storing small supplies, such as spikes, splice bars, track bolts, track and other tools. The respect in which the car is particularly convenient is that the appliances are arranged where they can be readily removed without having to handle over other material.

Tool Cars.—In order that wrecking tools may be readily accessible when they are wanted it is necessary to have systematically arranged tool cars. Many of the large railway systems go to considerable expense in fitting up tool cars, providing for the purpose cars mounted on passenger trucks, on the style of a baggage car and about the same size. An ordinary arrangement is to have two covered tool cars in the wrecking train, one of which is divided into two compartments—one being used for tools and the other, provided with seats and perhaps berths and kitchen accommodations also, for the regular wrecking crew. As an example of a wrecking train and equipment of the better class, reference may be made to some of the details of the outfit of the Chicago Terminal division of the Pennsylvania Lines West, omitting mention of many kinds of tools and appliances to be found in any up-to-date collection of the kind. The wrecking train consists of five cars as follows: one steam derrick car, one truck car, one "maintenance-of-way car," one block and tool car and one commissary and tool car. The truck car is an ordinary flat car carrying four heavy trucks, and an assortment of center plates, side bearings, Janney knuckles for couplers, etc., in the "possum belly" underneath the car. The maintenance-of-way car is an ordinary flat car carrying a quantity of rails, ties, spikes and other fastenings, split switches and frogs, with a full set of track tools in the "possum belly."

The block and tool car resembles a baggage car in exterior appearance, and carries a large quantity of blocking, together with a portion of the tools, including the ropes. The latter equipment includes 3-in. manila rope in lengths of 30, 300 and 600 ft., two pieces of 5-in. rope 35 ft. long, and two pieces of 2½-in. rope 300 ft. long (for block and tackle), all except the last two pieces having hooks and links spliced into the ends. For the 3-in. rope there are three large snatch blocks which are used in the place of tackle blocks, being considered more expeditious when it comes to arranging tackle. There are eight 10-ton Barrett lever jacks, a 20-ft. piece of chain made of 1-in. links, two sets of Tilden rerailing frogs, two tarpaulins 30 ft. square, a large canvas apron for transferring grain from cars, with eyelets for attaching to the sides of the door; two Wells lights, 30 hand torches, 6 Cox torches, each arranged to set upon a staff; 12 bushel baskets, 12 coke forks and 20 scoop shovels. The oils are stowed away in a separate closet. Figure 390 shows interior views taken from both ends of this car. The various pieces of hose used with a fire pump on the derrick car are disposed overhead. At one end of the car the racks extend half way to the roof, and on top of the same space is provided for a few bunks.

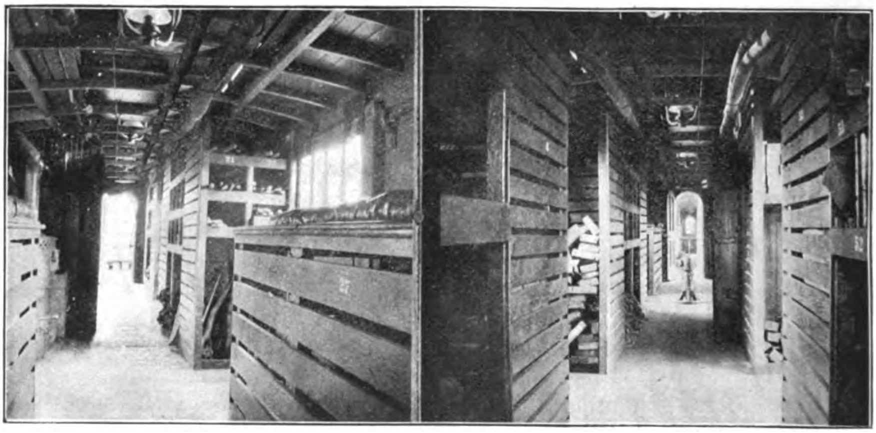
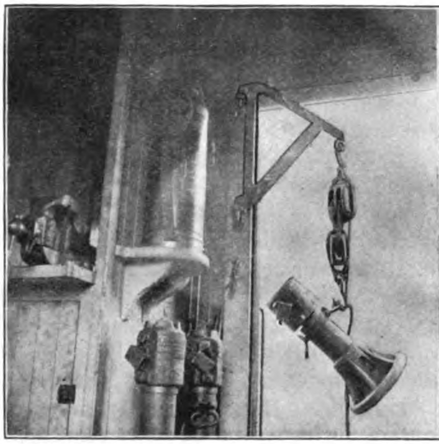


Fig. 390.—Interior Views of Blocking and Tool Car, Penna. Lines West.

The combined commissary and tool car is of coach construction and is partitioned off into a kitchen at one end and a dining room and sleeping apartment at the other. In the kitchen there is a range, with pantry, ice box, dishes, cooking utensils, and the usual assortment of canned goods and other common provisions are carried in stock. In the sleeping room there are lower and upper single berths, with other berths located in various parts of the car, provision being made, altogether, for 16 men to sleep in the car. The upper berths have hair mattresses. Extra bedding is also carried for 16 men, consisting of a double woolen blanket, two sheets, a comforter and one pillow for each man. In the sleeping end of the car there is an office desk, and a dining table 5x6 ft. in size, as shown in Fig. 392. The tools and other appliances carried in this car include, among other wrecking appliances, a box of carpenter's tools, one hundred 2-bushel sacks, fusees, aprons and bibs for handling meat in case of wreck to a refrigerator car, white, red and blue lanterns, 12 axes, extra telegraph wire, a fence wire stretcher, two Babcock fire extinguishers and four 30-ton and two 20-ton hydraulic jacks. There is an ingenious device for passing the jacks to and from the car, consisting of a small crane attached to the door post and arranged to swing out of the car, as shown in Fig. 391. The jacks are hoisted or lowered by means of a small set of block and tackle. The arrangement is found to be very convenient and a means of saving time. One of the fire extinguishers and a vise appear also in the view, which is somewhat distorted, owing to the unfavorable position of the camera in cramped quarters. The train is provided with air brakes and air signals throughout. The wrecking crew consists of a wreckmaster, an assistant wreckmaster and an engineer for the steam derrick, assisted by a gang of nine men, who work in the shops and reside near by. These men are within call at all hours. During working hours in the shops the call for a wreck is three short blasts of the shop



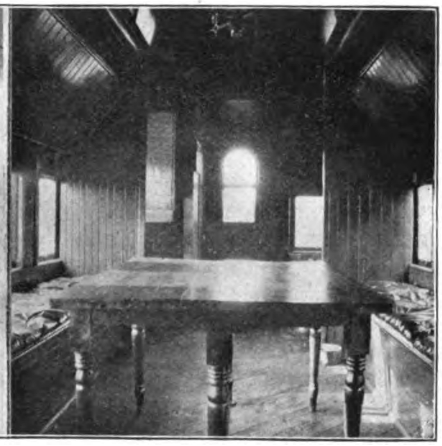


Fig. 391.—Crane for Handling Jacks. Fig. 392.—Dining and Sleeping Room. Commissary and Tool Car, Pennsylvania Lines West.

whistle. At night the men are called by an electric alarm system running around to the different homes. Ordinarily this crew handles all the work at wrecking, including slight repairs to the track. When the track is considerably damaged section men are picked up by the train en route to the wreck. In the commissary car there is carried a telegraph outfit neatly packed in a box, with wire and all facilities for setting it up at any point along the line. When running to a bad wreck the telegraph operator is taken from the nearest station and a telegraph office is set up at the wreck.

On small roads the tool car equipment is not usually as elaborate as the foregoing, and it is not necessary, for box cars can be fitted up quite as conveniently for the tools, and the work-train caboose can be used to carry the men. As a general thing the most extensive equipments are to be found with the larger roads, but the variety needed by the small road will be quite as large, if it should not contain so many pieces of each kind or so varied an assortment of each kind. The actual requirements of different roads may call for a different assortment of tools, in some respects, to suit special conditions, but in the main the list is about the same for all, so far as regards the most important tools or those most commonly used. In fitting out a box car for a tool car a large, new car, 34 ft. long inside, or longer, if possible, should be selected. The interior should have good light, which may be supplied by placing two windows in each side of the car, one on either side of the door, and a door in each end of the car with a window in the upper panel. There should be a cellar under the car, to hold rerailing frogs, chains, draw-heads, etc.; and a plank should be hung at each side of the car, under the door, to serve as a step, and convenient grab-irons should be provided for getting into and out of the car. Inside the car there should be hooks at the side, on which to string out the ropes; pegs for shovels, racks for bars, boxes and lockers for small and valuable tools, etc. There should be a flat-top heating stove well secured to the floor, some fuel, and a 6-gal. coffee pot; several packages of ground coffee, and a dozen tin cups for passing around hot coffee. There should also be a box properly lined for storing ice temporarily, which might be placed as a compartment of the cellar, underneath. There should be a small, heavy work bench with a 6-in, machinist's vise, and a good assortment of flat, quarter round, half round, and three-cornered files.

In one corner of the car there should be a closet or medicine chest under special lock and key. This closet should be supplied with a stock of medicines, instruments, bandages, stretchers, etc., such as any railroad surgeon can direct. It is desirable, however, to have an emergency chest containing such simple appliances as are usually administered in the way of "first aid to the injured," or when immediate professional assistance cannot be procured. The wrecking cars of the Cincinnati, New Orleans & Texas Pacific Ry. have ambulance chests fully equipped with muslin bandages, cotton (absorbent and carbonated), adhesive plaster, sponges, vaseline, tourniquet, scissors, and all the other necessaries for a complete emergency outfit, so that they can be readily available in case of need. With each chest are the following printed instructions for the information of the employees: "Arrest bleeding from wounds by pressure with a sponge moistened with cold or very hot water; if the loss of blood is considerable, apply the tourniquet. The pad of the latter must be applied to the inner side of the arm below the shoulder, in injuries of the arm; and to the front surface of the thigh, below the groin, in those of the leg. . . . . . . In small, clean-cut wounds, bring the edges together with strips of adhesive plaster; in wounds more than an inch in length, unite the edges with stitches. . . . . If the wound is ragged and torn, clean it as thoroughly as possible; then cover it with vaseline and a thick layer of cotton. Fix this dressing by applying a bandage as evenly as possible, and with moderate firmness. . . . . When a limb is evidently broken, place it in as natural a position as possible, until the local surgeon of the company can see the patient."

To carry the wrecking tools and appliances heretofore listed as essential to a complete outfit, at least two covered cars are necessary. Usually one car is needed for the ropes, jacks and chains. The most convenient place to carry track shovels, bars and spike hammers is in two large, strongly built and tightly covered boxes on a flat car. When box cars are used for tool cars the roofs of the same may be provided with flat racks for carrying the wire cables. The cables may be rolled up in large coils, and when carried aloft they should be securely tied in place. To keep them from rusting rapidly when thus exposed they may be painted.

The tool cars, with their contents, should be placed in charge of one man, who should have a list of everything in them, be accountable for everything leaving them, and, as far as possible, be expected to get everything back. He should live within easy reach of the car, and arrangements should be made to call him, either by day or by night, by an electric bell operated from the dispatcher's office. He should accompany the wrecking train on all occasions, and be provided with a cot or bunk so that he can stay with it; and provision should be made for some one to take his place in case of sickness. An ingenious blacksmith is the best man for such a position, because he can usually be given steady work about the company's headquarters, and time spent with the car can be considered part of his duties; and also because a blacksmith is always a handy man to have around any place where promiscuous work is going on. He should, after every occasion on which the tools are used, be allowed time to put the cars in order; repairing broken or bent tools; making requisition for those broken beyond repair, or for tools lost; washing dirty rope and splicing broken ones; cleaning and oiling tools, etc. The large blocks should be carefully examined after doing heavy service, taking them apart occasionally to inspect for bent pins, chipped sheaves or cracked strops. He should closely inspect the wrecking cars, including the derrick car, and see that the axle boxes are kept well oiled, so that they may stand a long, fast run without heating; in short he should have the cars, in every detail, always ready to go at a moment's notice.

The proper care of the large ropes requires considerable attention. They should be kept clean, and it is worth a good deal of pains to keep them free from oil, which greatly weakens rope. In order to have tackle overhaul freely the extra turns should be taken out of the new rope when it is uncoiled, and it should be rove with the lay. In using triple or quadruple blocks with tackle that is not liable to be pulled "block and block," the rope should be rove through the outside sheaves first and the middle or intermediate sheaves last. This arrangement crosses the ropes on one side of the tackle, but the hauling part of the tackle pulls directly on the center of the block and keeps it in line; whereas if passed through a side sheave it will cant the block with the first strain, and the ropes will not render freely. As it is sometimes necessary to lug tackle a considerable distance to a wreck, the best plan is perhaps to unreeve it each time it is put in the tool car and keep the blocks and rope separate. It is easier to carry in this shape, and, taking one time with another, more quickly rigged, than when carried around already rove. The ropes are also easier to clean, they will dry quicker after being wet, and the blocks are more accessible to inspection, if the tackle is unrove each time it is taken in from a wreck. Two good articles on the design of blocks and the rigging of tackle for wrecking purposes, by Mr. P. W. Hynes, of the Burlington, Cedar Rapids & Northern Ry., were published in the Railroad Gazette of Dec. 5 and 19, 1890.

Derrick Cars.—A wrecking outfit is never complete without a derrick car. Although its use is not always indispensable, scarcely no road can afford to be without one, because it can be used to much advantage in handling heavy objects generally. The lifting mechanism of a wrecking car is sometimes a derrick and sometimes a crane, but in common practice the distinction is overlooked and a car equipped with either machine is called a "derrick car." (The essential difference between a derrick and a crane is that the former is rigged with tackle for raising or lowering the boom, while in the latter the inclination of the boom, while lifting, is fixed.) The best derrick cars are made principally of steel. The frame of the car body is of steel I-beams or channels and the mast of the derrick (if a hand machine) is heavy riveted plate. As a means of increasing its stability the car is equipped with adjustable grappling hooks or tongs for fastening to the rail, and with car jacks for supporting the car under the side sills. The mast of a hand derrick car should be hollow and so arranged that a rope may be passed down through it, over pulleys, to be pulled by the locomotive, when convenient and desirable to do so. Steam derrick cars having a lifting capacity as high as 40 tons are extensively used, and are often made to lift a loaded box car bodily and swing it onto a flat car; and frequently a light locomotive is lifted bodily. Hand derricks are serviceable, but are slower of movement in lifting than steam derricks and are not made of nearly so large capacity, 15 tons being about the maximum.

The convenience of a derrick car depends a good deal upon the location of the derrick on the car. A derrick on one end of the car can reach farther over another car when loading than where the derrick is in the middle of a short car; but when it happens to come the wrong end to the work, it (the car) must first be turned around, thus frequently causing troublesome delay. Another advantage with the short car mounting a derrick in the middle is that pieces of the wreck, like a truck, for instance, may be lifted from the ground in front of the car and swung around and loaded upon a flat car in the rear; or in placing good trucks under wrecked car bodies, they may be taken from a flat car in rear of the derrick and swung around to the front. In either case the derrick has free action in front. The best form of hand machine is a car with a derrick on each end. It has the advantage of always having a derrick on the right end of the car, the lifting capacity of the two derricks can be united, and frequently both derricks can be used at the same time independently of each other. Hand derricks

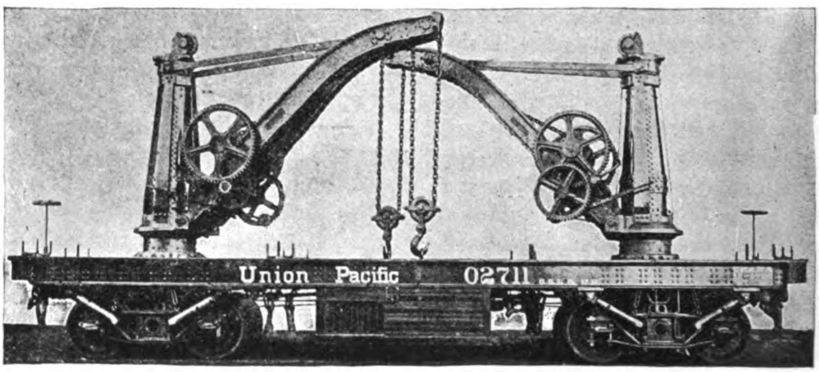


Fig. 393.—Hand Wrecking Car, Union Pacific R. R.

should have two speeds for lifting. The boom should be curved, so as to allow of more freedom of movement in turning objects lifted high, such as box cars, and its reach or radius should be at least 16 ft., and the lift at least 12 ft. above the rail. The lower block of the derrick should be heavy, so as to assist in overhauling the tackle, and at the same time short, so as to permit a maximum hoist for the hight of the boom. It should have a heavy swiveling hook. The stability of the car becomes less as the derrick works at a greater angle from the direction of the track. A beam or outrigger running out opposite the derrick mast and supported at its end by a jack or upon blocking, affords one means of increasing the stability of the car under a heavy side lift. The top of the mast should be provided with attachments for guy ropes, so that it may be stayed to surrounding objects when an extra heavy load is to be lifted.

Figure 393 is a view of a double-masted hand power wrecking car used on the Oregon Short Line branch of the Union Pacific R. R. (The standard wrecking cars of the main line are each equipped with a steam power derrick.) The car is 33 ft. long, 8½ ft. wide and weighs 69,235 lbs. The car frame is composed of four 12-in. I-beams and the masts of the cranes are constructed of rolled steel plates riveted together. The jibs are built up of steel channels and plates. The hoisting mechanism consists of spur gearing, arranged for two speeds in hoisting, and provided with an automatic brake which holds the load in any position and prevents the winch handles from flying back. The loads may be lowered by reversing the handles or releasing the brake. The capacity of each crane is 15 tons. When lifting on single gear the crank makes six revolutions to one of the drum and when on double gear, 11 revolutions to one revolution of the drum. The weight of the crane and machinery is carried by a series of steel balls upon the top of the crane post, and roller bearings are also provided at the base of the mast. Each crane is provided with a locomotive pulling attachment, for handling heavy loads rapidly, the rope passing over a sheave at the end of the jib, thence down through the mast and out under the car to the drawhead of the locomotive. There are four car jacks and four sets of rail tongs at each end of the car, and the car is air-braked. Under the middle of the car there is a cellar for carrying snatch blocks, ropes and chains.

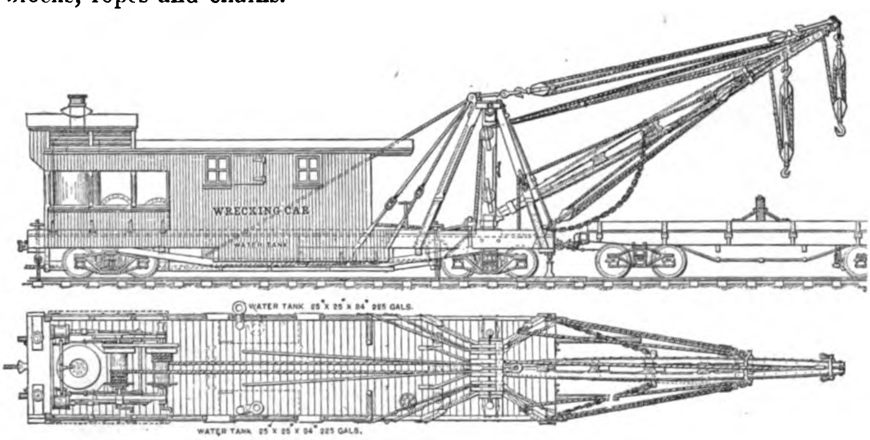


Fig 394.—Wrecking Car with Wooden Derrick.

Taking up steam wrecking cars in the order in which they were evolved, the first to receive attention are cars with wooden derricks, and such are still extensively in service and capable of doing heavy work. On general lines the car shown in Fig. 394 is typical of this style of construction, although certain details of the design are objectionable. The power consists of a double-cylinder engine with two drums, one of which works the tackle for raising and lowering the boom and the other the main lifting tackle suspended from the end of the boom. The tackle suspended at the shorter radius is worked by a locomotive line passed under the car deck at the foot of the mast and out under the rear of the car, as shown. Such is not generally used on a steam derrick car, but is drawn in the figure to show the arrangement for emergency and for derricks not operated by steam The car shown has a trussed boom, but a 12x12-in. stick of timber is frequently used for this purpose. For setting bridge material out ahead, a boom as long as 40 ft. is sometimes used, and on some roads as many as three booms of different lengths are carried with the car for various kinds of work. The boom is swung laterally by means of hand tackle anchored at the front corners of the car. The stability of the car in heavy side lifting is assisted by grappling tongs and body jacks, as shown. The front stiff-legs which brace the top of the mast, when arranged as shown, do not permit enough lateral swing for the boom, and in this respect the design is improper. These stiff-legs should brace the mast transversely with respect to the car, so as to permit the boom to swing to a right angle with the car. The sills of these cars are frequently built of steel I-beams or channels.

Figure 395 is a view showing one of the early types of steam wrecking car designed and built by the Industrial Works, of Bay City, Mich. It is in use on the Chicago & Western Indiana R. R., Great Northern Ry., Chicago & Eastern Illinois R. R. and other roads. The jib is a box girder constructed of plates and angles, and straddles a mast built as a Phoenix column. The forward end of the car is supported upon two locomotive trucks, the I-beams appearing just above the car floor, on either side of the mast, serving as equalizers. The jib radius for lifting is 24 ft. and the jib is supported cantilever fashion by two struts and two tension bars attached to a collar revolving about the mast. The inclination of the jib for lifting is fixed, but while in transit the jib is lowered to a horizontal position by slipping the pin holding it to the two tension bars. It is lowered or raised to or from the horizontal position by tackle operated by steam power. When in position for service the jib bears against the mast by a saddle about 4 ft. above

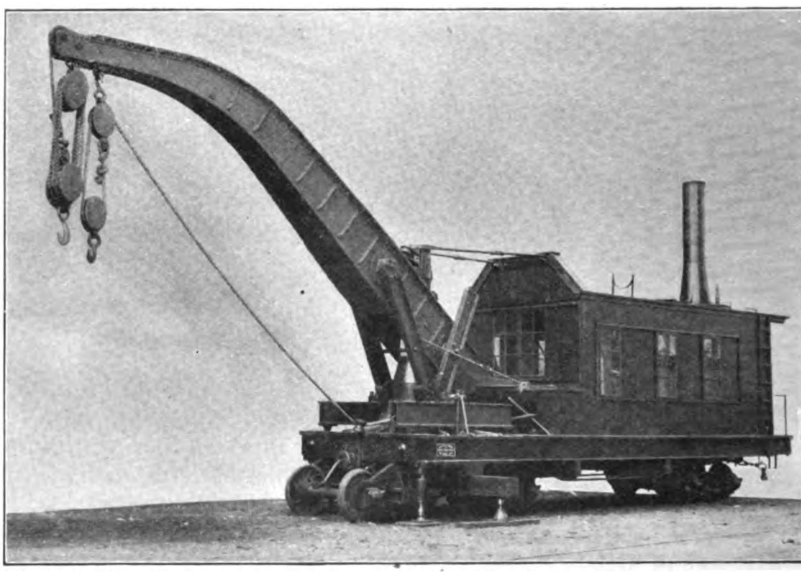


Fig. 395.—Steam Wrecking Car, Great Northern Ry.

the deck of the car. The lifting capacity of the crane is rated at 35 tons at a 24-ft. radius, but loads of 40 tons have been lifted by it repeatedly. The crane is turned by a pinion engaging with a segment gear at the lower end of the jib. The car is self propelling. The car body is of steel I-beam construction, and the total weight of car and machinery is 64 tons. Figure 396 shows an earlier form of this car, with the jib lowered into the horizontal position. With the exception of the jib, which is of tubular construction, of flanged and riveted steel boiler plate, the two cars are very similar. The plates of the jib are riveted to a heavy casting encircling the mast. The thickness of the plates varies from 5/8 in. at the casting to 3/8 in. at the end. Cars with this form of crane are in use on the Denver & Rio Grande, the Atchison, Topeka & Santa Fe, the Chicago & Northwestern, the Michigan Central, the Grand Trunk and other roads. The weight of the car (D. & R. G. R. R.) is 128,900 lbs.

An early design of steam wrecking car made by the Bucyrus Co., South

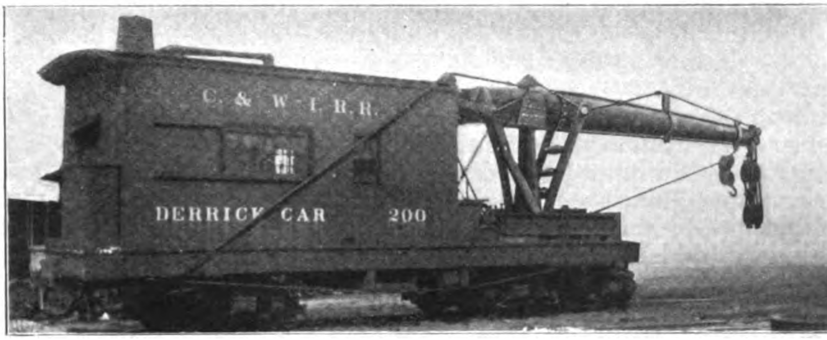


Fig. 396.—Steam Wrecking Car, Chicago & Western Indiana R. R.

Milwaukee, Wis., is shown in Fig. 397 in actual service. It is known as the "converted steam-shovel" type. It is carried on three heavy 4-wheel trucks, one at the rear and two at the front end, where the load is distributed from a center bearing on an equalizing frame between the car sills. The crane consists of a structural steel A-frame, pin connected, and a 33-ft. jib made of two 15-in. steel channels with cover plates, forming a solid box girder. The back guys and jib guys are solid steel eye bars, the latter (two) having a rear extension to provide for a pin connection with the A-frame when the jib is lowered to prepare for transit. The auxiliary equipment includes two removable winch heads, commonly called "nigger heads," for direct pulling independently of the main hoist, or for hauling the car along the track by warping. The jack arms, which are pin connected to the bottom member of the transverse A-frame and form a continuation of it, take the extra weight of loads lifted, and when not in service are folded up against the A-frame.

A more recent design of Bucyrus wrecker is the powerful machine illustrated in Fig. 397A. The lifting capacity is 100 tons on the 6-part hoist, 35 tons on the 2-part hoist at a radius of 30 ft., and 14 tons on the single-part hoist, same radius. The three hoists are ready for use at all times, and the single hook may be used simultaneously with either of the others. Loads may be lifted either by the hoists or by winding up on the boom. The end jack arms are pivoted at the upper corner of the car body and are balanced to swing out like a pendulum and remain in extended posi-

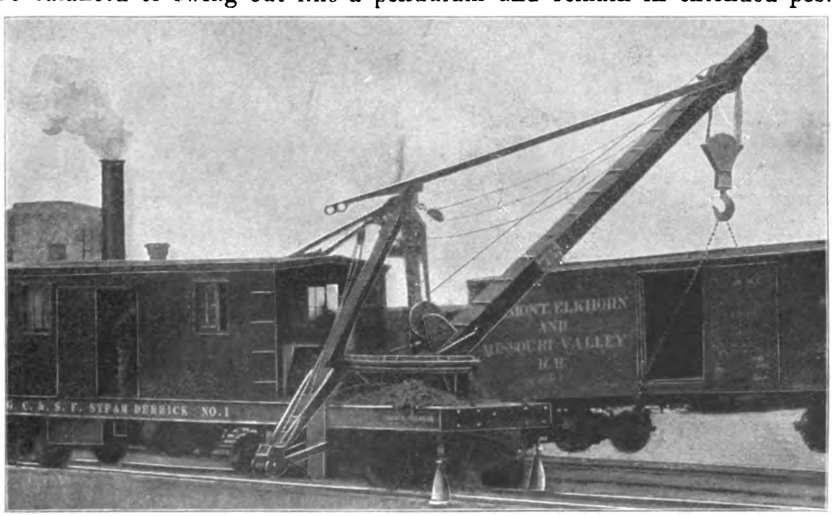


Fig. 397.—Steam Wrecking Car, Gulf, Colorado & Santa Fe Ry.

tion without being held. A bolt secures each arm in folded position during transit. The center jack arm is not used for loads under 60 tons at 16 ft. radius or 29 tons at 25 ft. radius. All the jack arms stand high and make room for substantial cribbing without digging. The car is 21 ft. long, permitting a load 8 ft. wide, at 16 ft. radius, to swing past the corner. The total weight of the car and machine is 87½ tons.

Figure 398 illustrates a type of modern derrick car, this design, on general lines, being standard with many of the large railway systems. The body of the car shown is of steel construction throughout, with longitudinal and transverse sills composed of 20-in. I-beams securely connected by plates and angles. The car is 24 ft. 1½ ins. long, 9½ ft. wide and runs upon trucks of especially heavy design with steel-tired wheels. Both air and hand brakes are provided. The engines are double, with cylinders 9x12 ins., fitted with link reversing motion. The hoisting is done with steel wire rope, but chain may be used for this purpose if desired. The raising or lowering of the boom, the hoisting, and the swinging of the derrick, are all accomplished by engine power. The radius of the boom ranges from 16 to 25 ft., and the extreme hight of lift (from the hook of the hoisting tackle to the rail) is 23 ft. On one end of the axle of the drum, outside its side bearings, there is a "nigger head" for hauling on loads direct. This car has three sets of outriggers, as follows: At each end of the car there are two telescopic steel I-beams 15 ins. deep, mounted on rollers carried by the plate brackets. These outriggers may be pulled 4 ft. beyond the side of the car, on either side, where they are supported on jacks with broad bases or upon blocking, as shown in the figure. In lifting loads up to 25 tons the end outriggers only are used, but for heavier loads there is a central outrigger of box section, formed of two 24-in. I-beams with cover plates, which extends to a distance of 10 ft from the center of the car. There are two of these, one for each side of the car, and being too long to be carried in position under

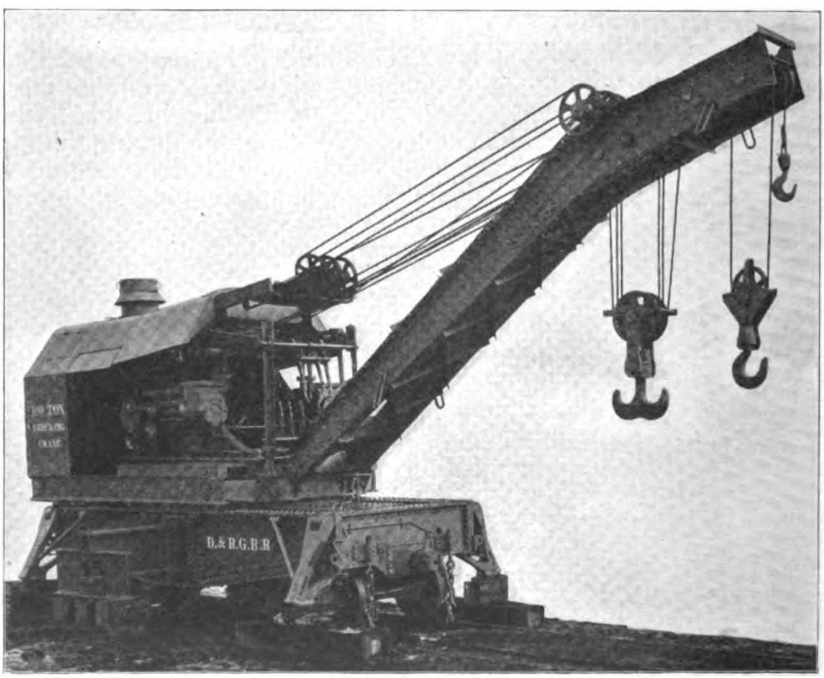


Fig. 397A—Steam Derrick Car of 100 Tons' Lifting Capacity, D. & R. G. R. R.

the middle of the car during transit, they are placed either upon the deck of the derrick car or upon the tool car, being easily swung to position by the derrick. The guide for these center outriggers is arranged in the form of a box with a removable cover plate at each end, so that it may be used as a tool box when the outriggers are not in place. The lifting capacity of the derrick, at a radius of 20 ft., with the outriggers in use, is 40 tons; at a radius of 25 ft., with the outriggers in use, 30 tons; at a radius of 16 ft., independent of the outriggers, 15 tons; at a radius of 20 ft., independent of the outriggers, 10 tons. In actual service these derrick cars frequently pick up one end of a 60-ton locomotive or lift a loaded box car or light locomotive bodily. The largest machines of this type are built upon heavier cars and have a lifting capacity of 100 tons. The engine is mounted in a heavy frame on a turntable with a circular rack, the boiler and water tank at the rear serving as a counterbalance for the boom. The turntable is at the middle of the car and the derrick can be swung through an entire circle with the load lifted. At each corner of the car there is a pair of heavy rail clamps.

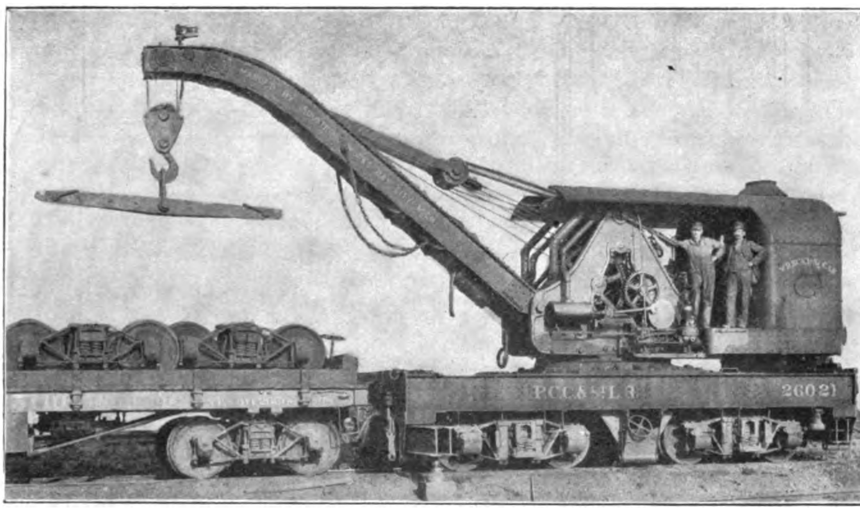


Fig. 398.—Steam Derrick Car, P., C., C. & St. L. Ry.

The particular derrick car shown in Fig. 398 was built by the Industrial Works for the Pittsburg, Cincinnati, Chicago & St. Louis Ry., and is in service on the Chicago Terminal division of the Pennsylvania Lines West. One of the interesting features in the equipment of this car is the provision for lighting when working at night, consisting of a Buckeye torch of 2500 candle power fixed at the end of the boom, and fed by a reservoir at the foot of the boom, as shown in the illustration. The pressure for the reservoir is pumped by machinery on the car. This arrangement fulfills a convenience which is much appreciated, as the light is always present in the direction in which the boom is working, it is out of the way, and is located so high that few if any things can intervene between it and the work to cut off the light. Another very useful auxiliary to the derrick car is a fire pump, arranged, as shown, just underneath the main hoisting engine of the derrick. This pump is provided with 125 ft. of 2½-in. wire-wrapped suction hose and 300 ft. of 1½-in. discharge hose. A novel feature of this part of the equipment is that the pump is detachable, and may be set up for duty temporarily at a distance of 125 ft. from the car, wire-wrapped steam hose of that length being provided to make the connection. As the pump can force a stream 90 ft. from the end of the hose, the radius of effective duty is more than 500 ft. The heavy horizontal bar hanging from the hoisting pulley of the derrick is known as the "singletree," and is used as a spreader when lifting a box car or locomotive, being placed over the top of the car or engine cab to prevent the chain from crushing in the sides. For lifting box cars two wire cables with L-hooks at the ends are attached to each end of the singletree and made fast under the side sills of the car. When the front end of a locomotive is lifted, cables are suspended from the singletree and fastened to the ends of the pilot beam; when a locomotive is lifted bodily the singletree stands parallel with the boiler. A particular advantage in the use of this device is that it divides the weight equally among the cables and hooks used in lifting the car or locomotive. All movements of the derrick when at work are controlled by bell signals given by a cord in the hands of the wrecking foreman.

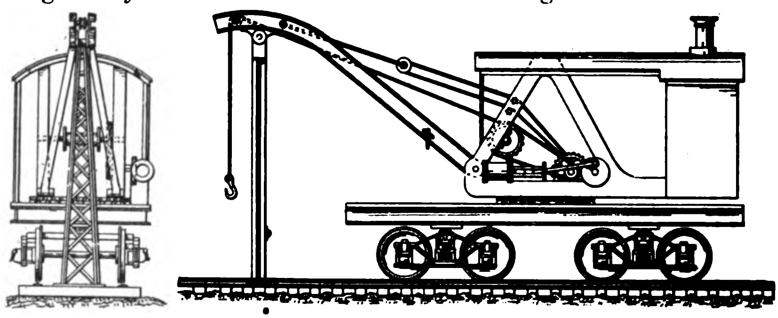


Fig. 399.—Stability Strut for Derrick Car, Norfolk & Western R. R.

On some roads a steam shovel is used for the wrecking car, the only change necessary to convert such a machine into a derrick car being the dropping or removal of the dipper, which, with some machines, can be quickly done. The hoisting capacity of some steam shovels is sufficient, of course, for ordinary wrecking purposes. The principal objection to the plan of depending upon a steam shovel for a wrecking car is the liability of delay. If the steam shovel is in service at the time it is needed at a wreck, the chances are that it will be found on an isolated piece of track or possibly at the far side of some gravel pit securely blocked in by 50 to 100 ballast cars put away for the night. Bridge erection derrick cars are very frequently called into service at wrecks.

To increase the stability of wrecking cars for very heavy lifting, especially for sidewise positions of the derrick, Mr. J. E. Graham, for some years wreckmaster of the Norfolk & Western R. R., designed and has used a bracing strut hinged to the boom of the derrick near the end, as illustrated in Fig. 399. The strut consists of two channel pieces diverging downwardly to a broad base plate which rests upon the track or blocking. These channels are cross braced, and when not in service the strut is folded up against the under side of the boom. When lifting is to be done that is beyond the capacity of the car with the ordinary stability supports, the strut is swung out and blocked up for the support of the boom. The strut is serviceable either for heavy straight pulling with the main hoisting tackle or for a heavy side lift. In either instance force may be applied to the full capacity of the hoisting engine and tackle without straining the derrick or car. Although the device cannot render assistance in cases where loads have to be lifted and swung, nevertheless there are many situations in which it should be useful; as, for instance, for quickly raising a locomotive into a more favorable position for blocking, or for rolling over a locomotive which has fallen upon its side, or for pulling on a locomotive straight away, with the main hoist.

Running to Wrecks.—The wreck train proper consists of a locomotive work-train caboose, tool cars and derrick car, and all should be air braked. These cars should stand on a side-track near the shops and where egress to main track cannot be blocked by other cars. Steam derrick cars are usually kept with a banked fire in the boiler, so that steam can be raised quickly. It is well to always have a car loaded with spare freight trucks, and another with about 20 rails and 200 ties, to take along, unless it is known before starting that such material will not be needed. On some roads the truck car is provided with a light hand crane for lifting the trucks to and from the car. This outfit consists of an ordinary flat car with the crane set in the middle of the car, the bottom of the mast being supported beneath the car floor, so that the car decking acts as a stay instead of guy ropes or rods. A locomotive truck is sometimes habitually carried on the truck car. The work-train kitchen and bunk cars and a cook should be taken along or sent out at first opportunity, because men called suddenly to go to a wreck do not always have time to get a good supply of lunch, and through excitement and hurry no attempt is usually made to provide anything to eat until the men are nearly famished; and then, owing perhaps to the remoteness of the locality or to misunderstanding, somewhere, it is sometimes not possible to get anything to eat for several hours longer. Many old trackmen know how it feels to work hard at a wreck for 12 hours or longer without anything to eat. When men get real hungry there is then something besides the company's interests which will engage their attention. Perhaps the safest way, under any circumstances, is to keep on hand in the tool car at all times a barrel of soda crackers or hardtack and a case of canned meat. As it sometimes takes several days to pick up a bad wreck, it is well to have the bunk car at the nearest side-track and to let the men have sleep, if needed, as soon as the track is cleared and put in running order. More profitable work can be done in this way than by working men completely out before giving them time to rest. The wrecking train can then remain at the wreck until everything is done, and waste no time running to and fro, if the distance to headquarters be considerable. Where it is seen that a long job is at hand the best method to pursue is to divide the men into day and night shifts, at the first.

When taking the first report of a wreck the train dispatcher should endeavor to get all the necessary information from the man giving the report; otherwise only a meager idea may be had of what is on hand. The matter of first importance is, of course, to ascertain whether any one has been killed, or injured seriously, and to what extent, so that medical assistance may be sent. At a bad passenger wreck it is best to send a surgeon whether injuries are reported or not, because a railroad company is often sued for injuries which are not made known on the spot. And it is best to send a company surgeon, because he understands the importance to the company of making thorough examination of the injuries at the first. The exact location of the wreck, the cause and time it happened; the length of track torn up or blocked; the condition of the locomotive, if wrecked, and its position and location with respect to the track; the number of cars off the track, in what condition, and with what loaded; the number of cars each side the derailed or wrecked ones; whether the derrick car is needed, and from which end it can work to best advantage; and what track material is needed, if any, are information that is indispensable to the train dispatcher. In case of double track the report should state particularly whether both tracks are blocked, and, if so, which one can be cleared first; or whether one track is clear, and which; and in any case whether there is a side-track through which trains may be got around the wreck. What trains, if any, are being held by the obstruction; what working forces have gathered at the wreck; what must be done to get the track clear; how many empty cars, and what kinds, are needed to hold the freight to be transferred, and such other information as circumstances may dictate should be ascertained and made known to the man in charge of the wreck train before he starts.

Some railways have a list of numbered questions covering all the information usually desired, arranged in the form of a blank report, and a supply of these blanks is kept on hand at all telegraph stations. In transmitting a report the operator then gives only the numbers of the questions and their answers. Some railway officials prefer that the first information of the wreck shall be a primary telegraphic report, stating briefly "what happened, where it happened, when it happened and what is needed." This enables the dispatcher to order out the wrecking train in the shortest time possible, and in the meanwhile the conductor of the wrecked train can think out a more complete report, which would likely be forwarded before the wrecking outfit would be ready to start and would probably cover more desired information than would be the case if he attempted to tell the whole story when first arriving.

The work train or wrecking crew, if at their homes, are usually called out by many long blasts of the locomotive whistle (thus arousing the whole neighborhood) or by messengers sent from house to house. In some cases where the organization of the crew has been carefully planned, the homes of the crew are connected with the dispatcher's office by electric bell or by telephone. If there is no crew organized, and the work train proceeds to the wreck during working hours, one may be made up by picking up the section men along the road, while on the way; or if after working hours, all available men at headquarters should be pressed in, and section men who can be reached by wire should be notified to get ready and flag the train when it comes, so that there shall be no needless stopping in anticipation of getting section men who fail to show up. Then if a sufficient force is not had by the time the wreck is reached, recruits should be brought on the first train following. If the work train is out on the road when the wreck occurs it is not usually advisable to have it first run a long distance back for the tool and derrick cars, but to send it (the work train) immediately to the scene of action and send the wrecking cars with a heavy engine to take the place of the other in case it be too light for the work, or to assist it. If a locomotive in the wreck is badly off the track both engines will be needed. It will frequently happen that in this way the work train, with the switch rope and the few other appliances which it always carries, will be able to have the track cleared before the wrecking outfit arrives. In this connection, also, the locomotive of the wrecked train, if able, should be set to work as soon as possible to clear main track; and section foremen should have the understanding that whenever they hear of a serious wreck within 10 miles they should go to it as soon as possible with hand car, men, and tools, without waiting for special orders.

Where the headquarters are at one end of the division this arrangement of wrecking with the work-train crew is no doubt as expeditious as any, because the train in daytime will always, if working, be in the direction of the wreck, and sometimes near by, so that by a little extra effort in some way, word can usually be got to it without much delay. At night the work-train crew, if at headquarters, can, of course, be called out as soon as any other crew, and in the same manner. If the work train was lying out on the road at night it could get off more quickly, for the crew would be with the train. For this reason the work train should lie over, with steam up, at a station where there is a night operator; or at any rate an operator should be sent to the station to remain during the night, if a night operator is not usually stationed there. Where, however, the headquarters are at some intermediate point of the division, a wrecking crew taken from the shops would probably be able to get to a wreck with less delay in most cases during daytime, and certainly so in any case where a work-train crew is not steadily employed. The wreck train should carry a telegraph operator, who is a lineman, who should tap the wires as soon as he arrives at the scene of the trouble, put himself in communication with the dispatcher, and keep him informed of the progress of the work, so that trains may be moved as soon as the track is clear. The best arrangement is to have this man employ his time with the crew, whether a telegraph office is needed at the wreck or not. In many instances this plan proves more satisfactory than that of taking an operator from a near-by station or even that of taking one along from headquarters when it is thought he might be needed. In any case the crew must necessarily include a lineman, or a man who is able to use pole climbers, as very few telegraph operators are likely to be found equal to such a task. The lineman of the wrecking force should make the necessary splices and put the line in its original condition after the wreck has been cleared up, thus saving the expense of sending a line repairer.

The use of the telephone on railroads affords a convenient and ready means of communication with division headquarters in time of wrecks. Some railway systems have telephone wires on the right of way along the main-line divisions and the more important branch lines. Where such a circuit is at hand the wrecking outfit should include a compact telephone set, which may be attached to a telegraph pole at the scene of the wreck, establishing direct means of communication with the dispatcher, the superintendent or with the signal towers at the ends of the block, as soon as connection is made with the circuit. On the New York, New Haven & Hartford R. R. use has been made of portable telephone instruments on such occasions.

At the last switch passed on the way to the wreck the locomotive should be shifted and the train approach the wreck made up in the following order: derrick car, truck car, blocking car, locomotive, tool cars. If the truck car has a crane of its own, or if the derrick of the wrecking car does not swing through a complete circle, the blocking car should then be coupled in next the derrick car. A flagman should be left at this switch and the track should be kept clear that far back. Empty cars taken along to be loaded with transferred freight should usually be left in a near-by side-track until they are needed. While switching, the men should get out such tools as will surely be needed—ropes, jacks, etc.—and place them on the derrick car. If the men work lively they can do this without holding the train much, if any. But such preparation might be made before, while running, in case the derrick car happens to be coupled next the tool cars. In the other direction from the wreck a flagman should be put out, and the locomotive of the first train arriving should be brought up to help clear the wreck from that side. Where oil tank cars have been wrecked and oil is lying around on the ground there is danger in running a locomotive or steam derrick car into the vicinity, and unless a good deal of caution is exercised there is liability of setting the whole wreck on fire. One way to do the work and still keep the locomotive away is to push the derrick car up to the wreck at the end of a string of cars. Oil lying exposed may be covered with dirt, and if work is to be done at night lanterns or closed lights should be substituted for hand torches. Although it is to be assumed that ordinary men would be cautious about handling lights in the presence of highly inflammable or explosive materials exposed in a wreck, it might be best in some cases of the kind to suspend night work altogether, especially if there is a clear track around the wreck. In all cases when beginning work at a wreck the wreckmaster should ascertain the character of all freight involved in the wreck, so that precautions may be taken in case there is danger of conflagration or explosion. Where oil cars are on fire or in danger of taking fire and cannot be got out of the way, the wrecking crew should endeavor to get everything movable out of reach as soon as possible, so as to prevent the fire from spreading.

Clearing and Picking Up Wrecks and Aid to the Injured.—The first duties of a train crew in time of a wreck are to see that signals are placed to protect other trains, to look after the injured, if there are any, and to protect the wreck from fire. Railway surgeons recommend that when a person is bleeding freely the limb or bleeding part should be elevated and the edges of the wound should be drawn together. A closely folded clean handkerchief may be applied to the wound and tied snugly, but some judgment must be exercised as to the time, or the bandage may be kept on too long. Cloths wrung out of hot water and applied to the bleeding part are a good means for stopping bleeding. When a person is suffering from shock the head should be kept low, on a level with the body, so that blood will flow easily to the brain. To keep the blood in circulation warmth should be applied to the body, and the hands and feet should be rubbed. A crushed or fractured limb should always be supported, and a temporary splint may be applied to prevent the broken bones from doing additional injury to the flesh. For transporting persons who are seriously injured, common passenger coaches are better than Pullman cars. The winding entrances of the latter are inconvenient for the passage of stretchers, making it necessary to handle the bodies by other means. The seats of ordinary day coaches are also easier to arrange for the reception of persons on stretchers, and they permit the injured to lie in better position for surgical aid.

Many railways have established schools or meetings wherein train and other employees are instructed in what is commonly known as "First Aid to the Injured," and in the use of emergency appliances for injured persons. On the Pittsburg & Lake Erie R. R., for example, the emergency box contains bandages, assorted sizes; sublimated gauze, rubber tourniquet, cotton, safety pins, etc.—enough to care for two or three injured persons. The folding stretcher contains two blankets and one rubber blanket, and four splints, assorted. Each caboose and each baggage car has a set of these supplies, and each station and telegraph office is similarly supplied. A small handbook has been issued to the men, and a circular has been placed in the hands of the men, entitled "Aid to Memory," an abstract of which is as follows:

First Aid Package.—For small wounds on any part of the body.

Gauze.—For large wounds.

Cotton.—To cover over on top of the gauze.

Rubber Band (Tourniquet).—To fasten around a limb or around the head to stop hemorrhage, particularly in case of crushed limb.

Adhesive Plaster.—To hold dressings, but never to be applied to an open wound.

Cotton Bandages.—To be used over first dressings where there is much bleeding.

Gauze Bandages.—To fasten splints in place and to support light dressings where there is no hemorrhage.

Safety Pins.—To fasten bandages, etc.

First—Don't give a drink of whisky.

Second—Don't pour ice or very cold water on wounds.

Third—The patient should be placed on his back, with head low, and this position should be continued in transporting.

Fourth—If the person is suffering from "shock," that is, pale with pinched expression of face, drooping eyelids and cold surface of body, with feeble pulse, give spoonfuls of hot tea or coffee; if this cannot be had, teaspoonful of whisky or some other alcoholic stimulant, in a tablespoonful of hot water every ten minutes until five or six doses have been taken. Wrap in a warm blanket and put hot water bottles or heated bricks about the body.

Fifth—Remove the clothing from the wounded part by cutting it away. Do not attempt to tear or draw clothing off, as this may further injure the wounded part. Always see the wound and know by your eye just what the nature of it is.

Sixth—If a limb is crushed or torn, apply over the wound a thick pad gauze, then a large covering or pad of cotton, fastened with several turns of the bandages, handkerchief or an elastic suspender.

Seventh—Hemorrhage. This follows shock and is very rarely severe unless reaction takes place. Too much stimulation increases hemorrhage, and for this reason it is best to give only a little stimulant, well warmed, and repeat the dose if reaction is delayed. Bleeding is of two kinds: First, arterial, when the blood comes out bright and red in spurts; second, venous, when the blood is dark and flows in an even stream. Avoid trying to stop bleeding by twisting cords or handkerchiefs around limbs with sticks. When the wound is large and blood comes out in spurts, apply the rubber band tightly just above the wound, previously raising the wounded member or part, especially if it be a limb. Be careful to put the band on uninjured flesh (if the limb be crushed) and about 3 ins. above the crushed tissues, else it will slip down and increase the hemorrhage. Be careful to see that the band be firmly hooked and fixed before leaving it. Small wounds, even though the hemorrhage be arterial, require only a firm compress of the sublimated gauze, placed immediately over the wound and bandage tightly in place with one of the muslin bandages. It is best after this to bandage firmly from the extremity of the hand or foot upward to beyond the wound with muslin bandages. Venous bleeding, which occurs when the wound is shallow (does not go deeper than the skin), as a rule, requires firm pressure over the wound, and especially below it. If the wound be quite small, put a pad of styptic cotton into it and over it and bandage tightly in place and then apply a bandage from below upward. If only the scalp is involved, it may also be controlled by drawing a rubber band around the head, encircling it just above the eyebrows. This is very painful, however, and unless the bleeding is severe, it may be controlled by bringing the wounded or torn surface together and applying along the wound a thick layer of styptic cotton, and over this another layer of absorbent cotton and a tight muslin bandage. It is well to pass the bandage under the chin if the wound be on top of the head, as this holds it firmer and tighter.

Eighth—After hemorrhage has been controlled apply gauze next to the open wound, always, and never let an open wound remain uncovered longer than is absolutely necessary to control the hemorrhage; but remember, a soiled or dirty covering is worse than none at all.

Ninth—If a leg or arm is broken, straighten it gently and lay on a pillow, then tie the pillow up with several strips of muslin, bandage or splints found in the stretcher. Laths or barrel staves, padded with some soft material, may be used for this purpose. This should be done before the injured person is moved any distance.

Tenth—Compound fractures are fractures accompanied by a wound of the soft tissues at the point of fracture, so that the bone is exposed to the air. In these cases treat hemorrhage and the wound according to the foregoing rules and then apply splints. If the bones project beyond the skin, remember to bring them back into place by pulling the extremity in the direction of the displacement until the ends of the fragments are quite free from over-riding. Remember to always cover these wounds with the sublimate gauze and bandage.

Eleventh—Burns. Carefully remove the clothing by cutting it off, if the part be clothed, and apply immediately three or four thicknesses of the sublimate gauze (dry or wet, in warm water in which one tablespoonful of the bicarbonate of soda to the quart has been dissolved). As a rule never attempt to clean burns immediately after they occur. Cover the wounded part immediately, as directed above, and leave the cleansing to the surgeon afterward. Extensive burns are attended with great shock, as a rule, and require free

stimulation. As the burns are rarely followed by hemorrhage, stimulants may be, and should be, given in considerable quantities.

Twelfth—Prostration from Excessive Heat.—In these cases (not sunstroke) the face is pale, lips colorless or blue, breathing slow, pulse slow and very weak. Place the patient on his back, with his head level with his body and loosen clothing. Apply heat to the surface of the body and extremities. Bathe the face with warm water into which a little whisky or alcohol has been poured, and if he can swallow, give the patient an ounce of whisky in as much water. When prostration is caused by drinking too much ice water when overheated, the face is red or even purple, breathing heavy and irregular, pulse irregular. Loosen clothing, place on back, with head slightly elevated. Give hot drinks, apply heat to the spine and the extremities.

Thirteenth—Position in Which a Person Should be Placed After Injury.—Injuries to the head require that the head be raised higher than the level of the body. In all cases, if practicable, lay the patient on his back, with the limbs stretched out in their natural positions; loosen the collar and waist bands, and unless the head be injured, remember to have the head on the same level as the body; do not bolster it up with anything.

Fourteenth—To Place a Person on a Stretcher to Carry Him.—Three persons are necessary to do this; two to act as bearers of the stretcher and one to attend to the injured part. Place the stretcher at the head of the patient, on a line with the body, the foot of the stretcher being nearest the patient's head. One bearer kneels on each side of the patient and joins hands underneath his hips and shoulders with the bearer on the opposite side. The third man attends to the wounded limb or looks after any bandages or splints that may have been applied. The bearers then rise to their feet, raising their patient in a horizontal position, and by a series of side steps bring the patient over the stretcher. He is then lowered gently on it and made as comfortable as possible. One bearer starts off with his left foot and the other with his right; should they keep step, the stretcher would roll badly.

When a freight train is wrecked the wrecking crew should include a check clerk from the freight department, or one who is familiar with methods of accounting for freight transferred. This man should carefully examine damaged goods, keep a record of damaged or destroyed freight, and obtain on the spot all other information which might be necessary for the uses of the claim agent. In too many instances such accounting falls to the wrecking foreman, who should be relieved of all duties minor to that of clearing the track and picking up the wrecked property in the most expeditious and economical manner. Where different kinds of freight are mixed up, or where only one empty car can be run into position for loading at a time, it is sometimes necessary to load the freight indiscriminately and move it to some convenient point for assortment.

The first work to perform on a wreck, if too much will not be sacrificed, is to clear the track of obstruction and put it in condition to let the traffic trains pass slowly. In some cases of very bad wrecks the quickest way of opening the road to traffic has been to lay temporarily a piece of track around the obstruction; but it can usually be done most quickly by placing on the track such cars as are in the way and easily got on; or by pushing aside those which are badly disabled; or by dragging them out, if there is not room to push them aside, as would be the case at a wreck in a through cut. Some cars may be so badly damaged as to be not worth saving. No care need therefore be given to the handling of such cars, and as a usual thing the quickest way of getting them out of the way is to cut them up. The initials and numbers of all cars destroyed should, of course, be reported. Where there is double track, one track, if clear, may temporarily be used by trains going in both directions, and then the work of picking up the wreck on the other track may be immediately begun without first clearing away. But if both or all tracks are blocked one of them must be opened up, and this should be the one requiring the least amount of work. The wrecking outfit of the New York division of the New York, New Haven &

Hartford R. R. includes a portable emergency crossover, devised by Mr. F. R. Coates, while roadmaster there, which is used in running trains around a wreck or other obstruction in case one of the tracks is clear. The device consists of frogs laid on blocking, to cross over and above the track rails, and raised switch points which are laid down on top of the track rails, thus lifting the wheels above the ordinary track rails. Under ordinary conditions it can be laid and made ready for the passage of a locomotive in from 15 to 25 minutes. It is also used for setting steam shovels, pile drivers and camp cars off the main line and in replacing derailed locomotives and cars. The Southern Pacific Co. has standard plans for laying temporary tracks around wrecks, washouts and other obstructions of like consequence. At each end the run-by turns out from main line by either a 10 or 15-deg. curve, reversing at the end of a 50-ft. tangent to bring the track parallel with main line. Figure 400 shows a diagram of the arrangement and tables of ordinates for staking out the curves.

If fastenings run short when laying track at wrecks, there are ways of "borrowing." Spikes may be obtained quickly by pulling every other one from the gage sides of the rails on tangent, and half the bolts may be taken from any of the joint splices. Where bolts have been sheared from one side of the track by a derailed car, as sometimes happens for long distances, half the bolts may be taken from the other side to secure the splice bars on the damaged side. Part of the spikes may also be taken temporarily from the gage side of a rail to replace broken spikes on the other side of the track or on the other side of the same rail.

Cars not badly off the track should be pulled on with the replacing frogs and hauled out of the way. In running wheels over blocking placed lengthwise, the flanges will cut into the wood and the tendency is to follow the grain. Cross-grained pieces are therefore not good for such service. A truck which has become skewed to the track may be swung straight by pulling on one corner of it with a switch rope. If the car is loaded, first take the weight from the truck by jacking, and block between the ties to keep the wheels from sinking in. A car body may be put to one side, out of the way, by lifting one end with the derrick and swinging it out, and by hauling the other end around on a skid with switch rope and snatch blocks so placed that the rope will pull away from the track. If no derrick is on hand the heavy switch ropes or the tackle may be used in this manner to drag cars out of the way. A car body may be rolled over by first unloading the freight and then catching hold under the sill and lifting with the derrick. On a high fill or steep bank cars put down the bank should be put aside endwise, so that they will not start rolling. A car body off its trucks may be dragged out by placing it straight with the track, lifting its front end with the derrick, placing a tie under it crosswise, and skidding it along on the rails, oiling the rails if the load is heavy. After hauling it some distance, ditch it by rolling over, if it be much damaged; or swing one end over at a time, hauling the hind end around with the switch rope attached to the hind corner toward the ditch and lifting the front end over with the derrick. It is almost always necessary to remove the freight from cars which are badly off the track. A car off its trucks and crosswise the track can be swung straight with the track by attaching a switch rope to one end and hauling it around on skids. It may happen that while the locomotive is hauling at the wreck a part of the force may accomplish a good deal on some other part of the wreck hauling on tackle by hand. The men are strung out along the rope and pull by the word. In a very heavy pull the 1-in. rope tackle may be used as the hauling part on the larger tackle.

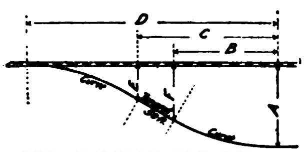
An easy way to get freight up a steep bank is to pile or lash a lot of it on a car door and then haul it up on skids, with tackle, by hand, or with the derrick or locomotive. Heavy boxes, castings, machinery, barrels of oil, etc., can usually be handled with the derrick. It is well to have two barrel slings for handling barrels or hogsheads by the chime, such as are used on board ships for that purpose. It consists of a piece of rope or chain with chime hooks at the ends and a ring at the center. If the freight cannot be transferred directly to cars and locked it is well to place a watchman over such of it as can be carried away, for there is usually an eager crowd standing ready to help themselves to the "spoil." When meat refrigerator cars are wrecked and broken open they should be boarded up as soon as possible, so as to keep the outside air from the meat. It may sometimes occur that extra refrigerator cars, newly iced, can be provided to hold meat transferred from wrecked cars, but if cars other than refrigerators must be used they should be swept out and well scrubbed. The floor should then be covered with a layer of clean ice in large cakes closely placed. If the meat cannot be hung up it may be supported on clean planks laid on the ice.

If trees or other stable objects cannot be found near enough to attach pulleys or guy lines, "dead men" or other anchorage must be put in. The planting of a dead man consists in digging a trench crosswise the direction of the pulling, and burying a log, piece of lumber or rail, or a tie, to which is attached a guy rope. The guy is led to the surface through another trench dug at right angles to the first one, at its middle, at a downward slant, so that the stress will pull the log against the bank of undisturbed earth instead of straight up. By looping the guy about the log and bringing both ends to the surface it may be got out, when through with, by pulling on one end with the locomotive. Or if it be desired to save the piece of timber or rail it may be got out quickly without digging by pulling straight up with the switch rope over a samson post. A wire rope sling about 16 ft. long is the best attachment that can be used. The ground should be looked over carefully and, if possible, each dead man should be placed where it can serve as a stay for pulling from several different directions. Idle section men or other men not used to wrecking can be doing this work while the engine is pulling at the wreck. There is a device, known as the Stombaugh guy anchor (Fig. 387B), which may be used in lieu of dead men. It consists of a helix 12 ins. in diam. cast around a heavy wrought iron bar of square cross section. The bar is 6 ft. long and the upper end terminates in a welded eye 3 ins. in diam. By means of a lever placed through the eye the anchor may be bored into the ground in a few minutes, and it can be removed with equal facility. As the ground is not greatly disturbed, the anchor will withstand a tremendous pull.

In picking up a wreck the old trucks and car bodies should be used, as far as possible, in hauling the wreckage to the shops. A car body may be put on trucks by the derrick car in the following way: Skid or roll the body onto, and straight with, the track, first getting a truck beyond it. Raise the end with the derrick and support the body just beyond the middle, so that the end next the derrick will slightly overbalance. A strong timber horse is sometimes provided for such support, but a handy one may be quickly arranged by supporting a piece of rail 14 or 16 ft. long upon a pile of blocking at either side of the track, or a car truck, with some blocking on top, will answer the same purpose. After the support is in place under the car let the derrick end of the body down. This will throw up the other end so that the truck may be run underneath it. Then raise the end again with the derrick, run a truck under that end, take out the rail or horse and let the end down upon the truck. It is well to see that the journal bearings are in place before letting the body down on to the trucks. A passenger coach is too long and too heavy to be handled in this way, and must usually be raised by the slower process of jacking. Place a jack under or near each corner and keep the car cribbed up as it is raised. A freight car body may be loaded upon a flat car by balancing it across a horse or other support and running the flat car as far under the body as possible. Then lift the other end and run the body on the rest of the way on dollies or rollers while the end is held up by the derrick. Whenever the air brake apparatus would be injured in handling a car it should first be removed and placed inside the car. Car bodies broken in two and disabled trucks are loaded upon flat cars. All pieces of iron should be picked up and thrown upon the cars. All traces of the wreck should be removed—either by loading upon cars, giving away or burning.

Considerable care must be exercised in handling passenger coaches that are but slightly damaged. As the tops of these cars are of light construction they cannot be hauled on as with the tops of box cars. When such a car is on its side it may be rolled by passing several ropes or slings through the ventilator openings in the roof, looping them around blocks padded with grain sacks and placed crosswise the openings, and bringing all these ropes to a common center, so that all bear as nearly as possible an equal stress. Where passenger coaches have rolled or run down a bank they can generally be got back easiest by laying a piece of track to them at an incline, diagonally down the bank, and hauling them up with switch ropes or tackle. A foundation for the track may be had by digging into the bank on one side and laying timbers or rails upon cribs of ties or blocking, to support the other side, or by cribbing under both sides. If the material cannot be obtained in any other way, it may be had by taking up some near-by side-track. This track may be hastily built, spacing the ties at wide intervals, and it may be connected to the main track at the top by cutting and throwing the main track over to it. The derrick car, if needed at the bottom, may be let down this incline. When a locomotive is to be hauled up a bank in this way a more substantial foundation for the track is required, and it might be necessary to cut a bed out of the bank the full width of the track. Where cars have run away from the track, on the level, they may be easiest got back by cutting the track and throwing it over to them between train times, or by building a piece of temporary track, to which the main track may be thrown to connect. The cars should be ready to haul onto the track as soon as it is thrown over. A car down the bank or to one side, resting on its sills, may be hauled to the track by swinging first one end and then the other, with the derrick. If the bank is steep the advantage gained at each hitch should be held by a rope anchored to the track rail.

A locomotive off the rails but not off the ties may be put on by using the replacing frogs or wedges and hauling straight ahead. It will frequently save time, however, to lay pieces of rail in front of the wheels and throw the track rails over to connect with them. In pulling locomotives or cars around very sharp curves on temporary tracks it is well to oil the rails. If one side of a locomotive is off the ties, sunk into the mud or ballast, and the machine badly tilted, or if it is tipped completely over on its side, not much can usually be done with the jacks. The locomotive may be righted by passing a chain around the dome and hauling on it with tackle attached to a dead man or other object off at the side. A collar or strap is sometimes made to go around the dome of a locomotive as a means of attachment in turning it over. In rolling over a locomotive a leverage may be had by lashing a heavy stick of timber to the side and pulling on the end of it. If the timber can be placed under the locomotive, the bottom end would be chained to the frame and blocking would be arranged for a bearing against the dome; otherwise, the timber lever would be applied to the top-side, with the foot bearing on the frame or against a driving wheel, and lifting by means of a chain around the dome. A start may be had by jacking against this timber for a ways, or by pulling over a guyed samson post, or by hitching the tackle to the top of a strong telegraph pole securely held with guy ropes. In righting a locomotive where one side is on the ties, lift the machine a few inches at a time and follow it up with blocking. If the locomotive is upright but sunk deeply into the earth, jack it up and run ties and rails under it before attempting to haul it away. Where an engine has gone down over a high bank or through a bridge, a powerful tackle must be arranged, and two or more locomotives will be required to haul it back. If it is overturned it must first be righted and put in line with a piece of track laid to it down an incline. If the incline is steep it is well to pull on it with double sets of tackle secured to several dead men or trees; otherwise it may be hauled by attaching to it directly with steel cables. It



10° CURVES					
A	B	C	D	E	F
10	53.6	103.3	156.9	2.5	7.5
20	84.0	133.5	217.5	6.3	13.7
30	107.3	156.5	263.8	10.3	19.7
40	127.3	176.0	303.3	14.4	25.6
50	144.8	193.1	337.9	18.7	31.3
60	160.3	208.3	368.6	23.0	37.0
70	174.5	222.1	396.6	27.4	42.6
80	187.8	235.0	422.8	31.8	48.2
90	200.2	247.0	447.2	36.2	53.8
100.	211.9	258.3	470.2	40.7	59.3

15° CURVES					
A	B	C	D	E	F
19	42.2	92.0	134.2	2.3	7.7
20	66.2	115.4	181.6	5.7	14.3
30	85.0	133.7	218.7	9.5	20.5
40	100.8	149.2	250.0	13.5	26.5
50	114.7	162.6	277.3	17.5	32.5
60	127.2	174.4	301.6	21.5	38.3
70	138.7	185.6	324.3	26.0	44.0
80	149.4	195.6	345.0	30.3	49.7
90	159.2	204.8	364.0	34.6	55.4
100	168.5	213.5	382.0	39.0	61.0

Fig. 400.

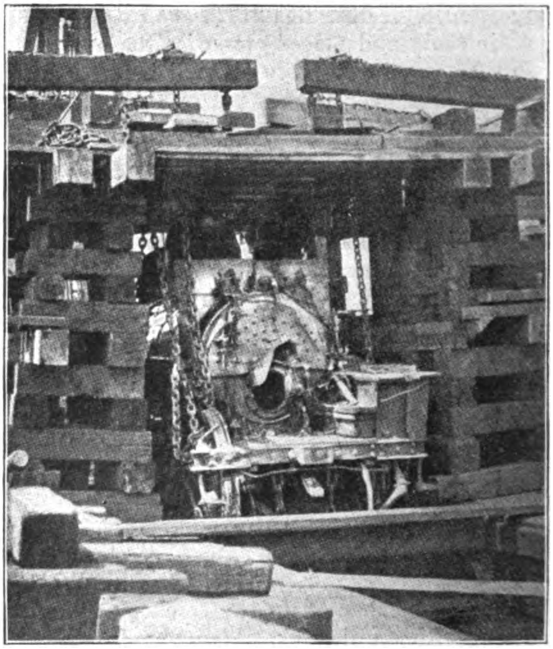


Fig. 401.—Rear View of Locomotive.

is usually best to first dismantle a locomotive, especially if it is to be much handled. The shafts, connecting rods, headlight and many other parts which might be damaged should be taken off; and the locomotive can also be pulled somewhat easier, especially if some portion of the driving parts are bent. Wherever close movement is required and heavy pulling is to be done there should be as few cars as possible attached to the locomotive that is doing the pulling, and in such cases the tool car, derrick car, etc., may be run back out of the way.

Cars which have fallen through a bridge into deep water are sometimes lifted out by a dredging machine and placed upon barges. For work of this kind the dipper and dipper handle of the dredge are removed and heavy block and tackle is hung from the boom. Locomotives may be lifted out of deep water by hoisting between two scows. Figure 402 is a view showing the manner of lifting a 44-ton locomotive of the Chicago, Milwaukee &

St. Paul Ry. out of 18 ft. of water in the Chicago river, the locomotive and passenger train having run into an open drawbridge. By the aid of a diver a line was passed under the boiler, just back of the cylinders, and this line was used to haul under a heavy chain. Another chain was made fast to a toggle placed inside the firebox door. Two scows, each measuring 85x22x6 ft. and capable of carrying 250 tons, were then run over the locomotive and partly filled with water so as to settle considerably. The chains were

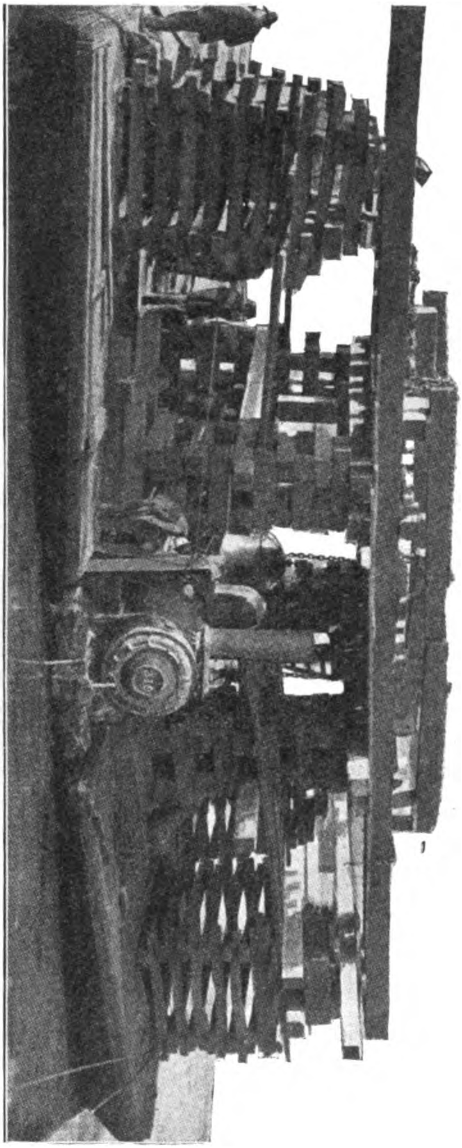


Fig. 402.—Raising a Sunken Locomotive, C., M. & St. P. Ry.

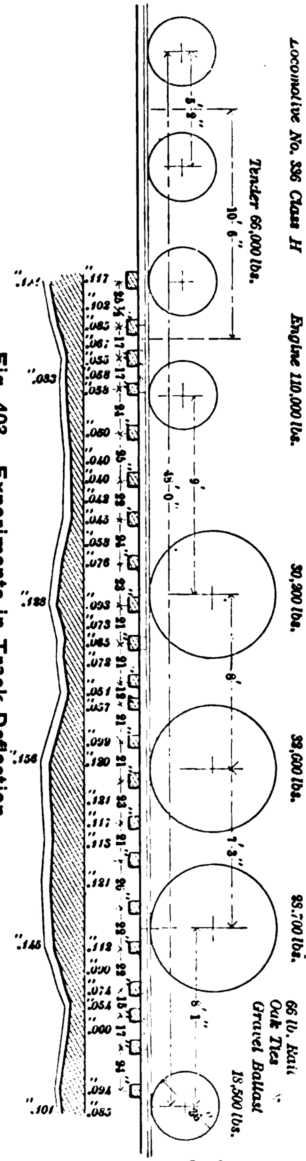


Fig. 403.—Experiments in Track Deflection.

then made fast to the scows, when the water was pumped out and the locomotive lifted off the bottom and carried farther from shore, in order to obtain more room. The locomotive was then dropped and the scows placed alongside—that is, one on each side of it—9 ft. apart and securely braced so as not to separate. In order to facilitate placing the locomotive on a track after being lifted, it was raised as near as possible to one end of the scows. Four 16x16-in. spruce beams, each 56 ft. long, were then placed crosswise the scows and supported on blocking 14 ft. high. Chains were then made fast to each of the four drivers, in addition to the chain looped under the head end of the boiler, previously noted, and passed to 12x12-in. oak levers supported on the spruce timbers, as shown in the figure. These levers were six in number, arranged in three pairs, and operated by screw jacks. The chains were held to the levers by toggles, and to hold the chains while dropping the levers, in order to take up on the chains, toggles were arranged on the beams underneath the levers. A rear view of the locomotive, in which these levers appear more clearly, is shown in Fig. 401. After the locomotive was righted and raised to a sufficient hight the scows were swung "end on" to a piece of track laid down the bank and supported at the end upon two piles driven into the bed of the river. The work was accomplished in 7 days with a crew of 14 men, considerable delay being occasioned by the limited room for handling the scows and the necessity for dropping the locomotive and raising it a second time.

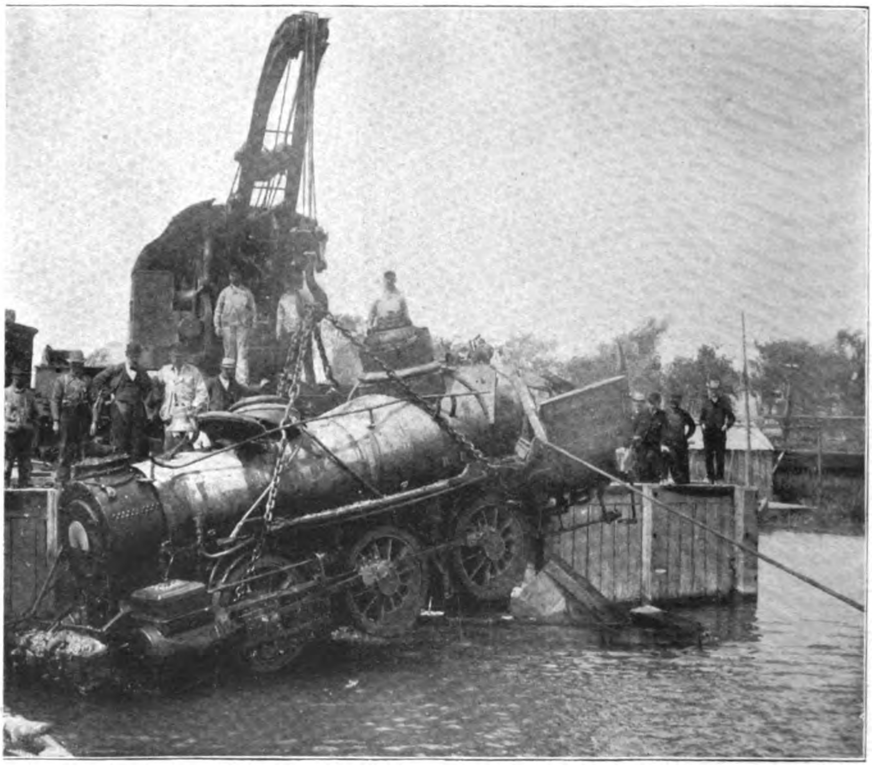


Fig. 404.—Recovering a Sunken Locomotive, Niagara Junction Ry.

In some cases locomotives have been fished up by running chains under them and fastening to water-logged scows. At low tide the scows would be pumped out, lifting the wreck, and at high tide they would be towed into low water. When the tide fell again the water logging and pumping operations would be repeated, and the locomotive carried shoreward until finally it would stand dry, with the tide out, when a piece of track would be laid to the site and the locomotive hauled away. At Terre Haute, Ind., a locomotive of the Cleveland, Cincinnati, Chicago & St. Louis Ry., at one time, was raised out of water by means of sets of heavy block and wire rope tackle fastened to a bridge. The tackle was pulled by a locomotive on the track over the bridge, and to prevent side strain on the bridge trusses the tackle was suspended from special wooden chords laid upon the bridge and secured against lateral movement or pressure by guy lines run to the shore. The wrecked engine was lifted 10 or 12 ft. above the water and let down upon a scow, and finally hauled away on a temporary track built to the scow landing. As heretofore stated, locomotives of light weight are frequently lifted bodily by steam wrecking derricks. An instance of such recovery is illustrated in Fig. 404. A locomotive and six freight cars of the Niagara Junction Ry. ran off the end of a dock into the Niagara river and sank in about 15 ft. of water. The picture shows a "Bay City" derrick car (like the one in Fig. 398) in the act of lifting the locomotive out, at a radius of 18 ft. The chains were fastened by a diver, and after the locomotive was lifted high enough to clear the dock it was swung around and placed upon the track. The weight of this locomotive was 42½ tons.

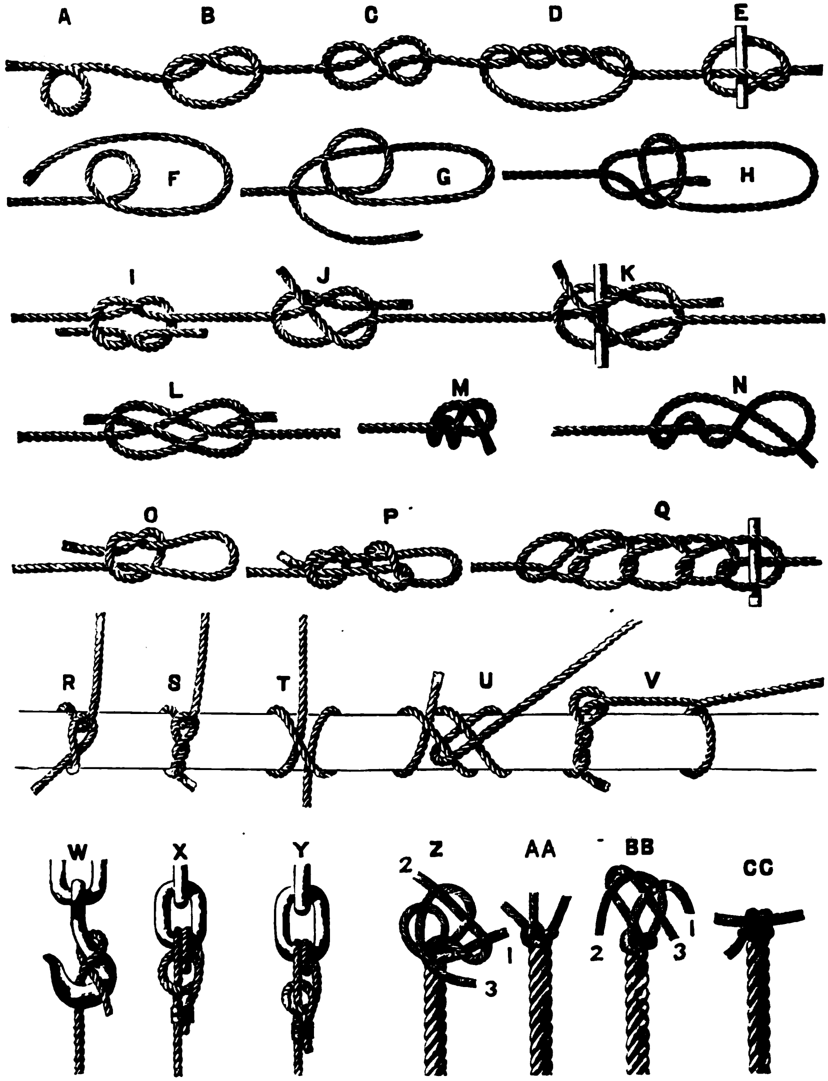
In the absence of the roadmaster, if he be wreckmaster, the foreman of the work train, or the highest assistant in authority under the wreckmaster who is present, should take charge until the wreckmaster arrives. The wreckmaster should keep his head cool and avoid hasty speech. Some men appear to think that a wreck gives them good excuse for cursing or abusing their subordinates upon the slightest mistake or irregularity; and some men in authority show more ingenuity in finding fault than in handling a wreck. On the other hand, there is no better opportunity for an official or foreman to gain the good will of his men than by keeping patient and civil while they are engaged at hard and hurrying work. He should give the signals to the engineer when ready to pull at the wreck and see that men stand clear where they will not be liable to injury by the breaking of ropes or chains. At night he should carry a lantern with a colored globe, so that he may be readily found when sought. He should be able to rig block and tackle to best advantage, and should acquaint himself with a few ways of making hitches and tying knots in large ropes. A knowledge of how to tie knots comes handy when ropes break.

Knots and Hitches.—Figures 405 and 406 show a number of the most common knots and hitches, the former illustration being reproduced by permission of the C. W. Hunt Company, West New Brighton, N. Y., from a plate published in a pamphlet entitled "Manila Rope." This publication also contains instructions for splicing ropes. In order to show clearly the position of the parts the engravings in Fig. 405 were made open, or to represent the rope before being drawn taut.

The principle of a knot is that no two parts which would move in the same direction if the rope were to slip should lie alongside of and touching each other. Sketch *C*, Fig. 405, shows the wrong way to attempt to tie a figure-8 knot, as it makes an overhand knot identical with *B*, except that one is right hand and the other left hand. Sketch *OO*, Fig. 406, shows the correct way to tie a figure-8 knot, the right-hand end going first under, and then over, the loop instead of over and then under, as in Fig. 405.

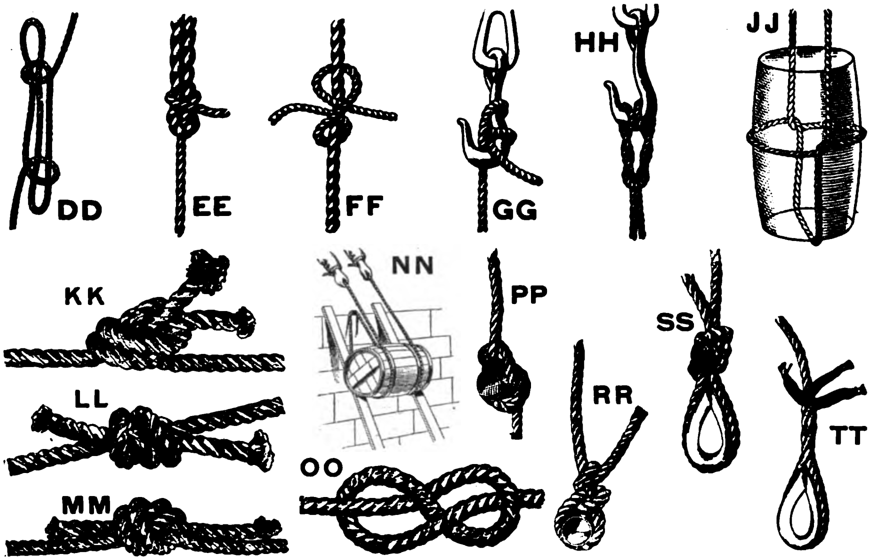
One of the most serviceable knots is the bowline, used in fastening a rope to a tree or post. It will not slip, and after being strained is easily untied. The three steps in tying the knot are shown as engravings *F, G* and *H*. in Fig. 405. The square or reef knot (*I*) is used in joining the ends of two ropes and is difficult to untie. If the short ends be wound together in the reverse way the result is a "granny knot," which will slip under strain. The weaver's knot (*J*) may be used to join the ends of two ropes or to fasten the end of a rope to a bight in another rope. The stevedore knot (*M*) is useful where a rope passes through an eye and is held by the knot, as it will not slip and is easily untied after being strained.

The Blackwall hitch is used for attaching the end of a rope or a sling to the hook of a block. When the rope spreads away to its load—that is, when both ends are attached to the load, as when using a sling—the hitch is made as in Sketch *W*, Fig. 405. This hitch causes the rope to jam when



A, Bight of rope.
B, Simple or overhand knot.
C, Figure-8 knot (wrong way).
D, Double knot.
E, Boat knot.
F, Bowline, first step.
G, Bowline, second step.
H, Bowline completed.
I, Square or reef knot.
J, Sheet bend or weaver's knot.
K, Sheet bend with toggle.
L, Carrick bend.
M, Stevedore knot completed.
N, Stevedore knot commenced.
O, Slip knot.
P, Flemish loop.
Q, Chain knot with toggle.
R, Half hitch.
S, Timber hitch.
T, Clove hitch or builder's knot.
U, Rolling hitch.
V, Timber hitch and half hitch.
W, Blackwall hitch (single).
X, Fisherman's bend.
Y, Round turn and half hitch.
Z, Wall knot commenced.
AA, Wall knot completed.
BB, Wall knot crown commenced.
CC, Wall knot crown completed.

Fig. 405.—Knots and Hitches.



DD, Shortened rope.
EE, Swab hitch.
FF, Clove hitch.
GG, Double Blackwall hitch.
HH, Cat's-paw hitch.
JJ, Barrel hitch.
KK, Open hand knot.
LL, Englishman's tie.
MM, Ordinary tie.
NN, Parbuckle.
OO, Figure-8 knot.
PP, Timber hitch (direct pull).
RR, Double half hitch.
SS, Flemish loop (taut).
TT, Eye splice.

Fig. 406.—Knots and Hitches.

the strain comes on and prevents the sling from slipping through the hook and tilting the load in case the latter meets with some obstruction while being hoisted. The rope is easily detached when the strain is relieved. If the end of the rope is to be used it should be passed twice around the hook, as in Sketch *GG*, Fig. 406. With only one turn, as in Sketch *W*, the rope is liable to slip when subjected to heavy pull, especially if it is wet. When the rope is too long for convenient manipulation of the end it may be secured to the hook by a cat's-paw hitch, Sketch *HH*, Fig. 406. This hitch is made by taking hold of the rope with both hands at points about 2 ft. apart and twisting it two or three times either way, when the ends of the loops thus made are applied to the hook. The twisting prevents the rope from becoming jammed and the hitch is easily loosened.

A wall knot, or wale knot (*AA, BB, CC,* Fig. 405) is a knot made at the end of a rope by interlacing the strands, and is used to keep the end from drawing through an eye or hole. It is made by proceeding as follows: Form a bight with strand 1 and pass strand 2 around the end of it, and strand 3 round the end of 2, and then through the bight of 1, as shown in the engraving *Z*. Haul the ends taut, when the appearance will be as shown in the engraving *AA*. The end of strand 1 is now laid over the center of the knot, strand 2 laid over 1 and 3 over 2, when the end of 3 is passed through the bight of 1, as shown in the engraving *BB*. Haul all the strands taut as shown in the engraving *CC*. By going a step farther than what is done in Sketch *Y* and making another half hitch, and then drawing taut, the end of the rope will hold without wrapping, and it then becomes a good hitch to make around a tree.

Sketch *DD*, Fig. 406, shows a method of shortening a rope which is too long for some temporary purpose. It consists of a half hitch at each end of one or more bights laid up to shorten the rope to the required length. If several bights are laid up the standing part is passed through the ends of all and pulled tight. The illustrations *EE* and *FF* show hitches for securing a small rope to one of larger diameter. In the swab hitch (*EE*) the end of the smaller rope is sometimes passed twice around the bight of the larger, instead of only once, as shown. Sketch *FF* will be recognized as the clove hitch, identical with Sketch *T*, Fig. 405. The hitch *JJ* is used on barrels and similarly-shaped things when it is desired to hoist the vessel in a vertical position. The illustrations *KK* (open hand knot), *LL* (Englishman's tie), and *MM* (ordinary tie) show various knots for tying the ends of two ropes together or for uniting the two pieces of a rope at a break. When the knot *KK* is tied in the bight of a single piece of rope it is known as a loop knot. Sketch *NN* shows the parbuckle hitch, for rolling a barrel or similar load up an incline with a single length of rope.

For heavy pulling with manila or hemp ropes the spliced eye (*TT*, Fig. 406) is the most efficient method of attachment, as it will stand a pull sufficient to break the rope in the straight part. Next in efficiency come the timber hitch, the slip knot and the double half hitch, in about the order named. Numerous tests made at the engineering laboratory of the Massachusetts Institute of Technology give the relative average efficiencies of various hitches as follows: Spliced eye, 100 per cent; timber hitch, 74 per cent; double half hitch, 69 per cent; slip knot, 73 per cent; bowline, 58 per cent; Flemish loop, 50 per cent. These figures apply to manila and Russian hemp rope. With American hemp rope the efficiencies proved to be higher in every case, being 84 per cent for the timber hitch, 90 per cent for the double half hitch, 92 per cent for the slip knot; 80 per cent for the bowline and 76 per cent for the Flemish loop. With cotton rope the eye splice was not found as efficient as the timber hitch.

None of the knots will withstand a pull as great as the strength of a straight rope. The Englishman's tie (*LL*, Fig. 406) is the strongest. The relative average efficiencies of knots, as determined by tests at the Massachusetts Institute of Technology, were reported as follows: Englishman's tie, 61 per cent; ordinary tie (*MM*, Fig. 406), 57 per cent; square knot (Sketch *I*, Fig. 405), 52 per cent; open hand knot (*KK*, Fig. 406), 46 per cent.

150. Fighting Snow.—The task of clearing the track of snow falls to the track department. In certain portions of the country, particularly in the Northwest or upper Mississippi valley states, the handling of snow is a work of much importance; indeed the regularity of the traffic in winter time depends much upon the alertness, the industry and, quite frequently, upon the ingenuity, of the man or men in charge of it. Of snow plows and other appliances in use for removing snow there are many kinds, but, generally considered, they may be divided into five types, namely: push plows, pilot plows, machine plows, wing plows and flangers. On eastern roads, or roads east of Chicago, the most common type of plow in general use is some form of push plow; between Chicago and the Rocky mountains the type of plow in most general use is the pilot plow; while on the Rocky mountain roads one finds the machine plow in common use.

Push Plows.—A push snow plow has fixed parts, runs upon its own wheels, and in operation is pushed ahead of one or more locomotives. The plow proper is usually constructed at the end of a flat car or box car, and it usually takes one of two shapes, namely, V-shaped or square-nosed. A plow shaped like a locomotive pilot would be one example of a V-shaped plow. Its tendency is to crowd the snow out or throw it aside without lifting it much. A V-shaped plow having its faces vertical, or perpendicular to the track, crowds the snow aside without lifting it any, and it becomes a difficult matter to hold such a plow down in compact snow. There is then the further objection that snow handled in this manner will fall back under the wheels after the plow passes. A square-nosed plow is one the front and lower edge of which extends squarely across the track the full width of the plow. Its action is first to lift the snow, as dirt is lifted in a scraper, and then to throw it aside, without crowding. The upper part of the plow is V-shaped. The face of the plow is in principle a rectangular inclined plane surface having a V-shaped plow of the same width set upon it some distance back from the front edge. For use in snow of moderate depth a plow at the end of a flat car is frequently employed. One such in the service of the Michigan Central R. R. consists of a wooden plow with vertical faces (V-shaped), suspended from the overhanging end of a 12x14-in. beam running longitudinally over the car and hinged to the frame of the car at the rear end. At the front end of the car there are two vertical brake cylinders, one at either side of the beam, for lifting the plow at crossings and switches. These cylinders are supplied with air piped from the cab of the locomotive and are under the control of the engineer, who raises and lowers the plow as necessity requires. It is therefore not necessary to the operation of the plow that an attendant should remain on the car. The car is weighted down and is pushed ahead of the locomotive. The Pennsylvania R. R. has a plow of somewhat similar construction, the front and rear ends of the car being loaded with old car wheels. At the front end of the car there is a plow, and just back of the front truck there is a flanger. This flanger is attached to the ends of two struts hinged in front of the rear truck of the car and raised either by an air cylinder or by a long lever, which is used when air pressure is not available. The Boston & Albany R. R. also uses a snow plow rigged at the front end of a flat car. The plow device is 6½ ft. high and there is a small house or cab on the car for the pilot.

One of the best known push plows is the Russell design, first put to service in 1885 on the Intercolonial Ry., in Canada, and now used on a large number of roads. This plow is of the square-nosed type and is very solidly built. The incline or face of the plow is formed upon a 12x12-in. white oak timber known as the "backbone," and the plow is pushed at the front end by a 12x12-in. oak timber called the "power bar," which lies between the two center sills of the car frame, extending the entire length of the car to the "backbone," to which it is hinged by heavy straps. The rear end of the timber is left free to move laterally a distance of 4 ins. each way from the center, so that it readily adjusts itself to curves. The nose of the plow or cutting edge is 10 ft. wide and reaches within a few inches of the rail. The rear portion of the car is 6 ins. narrower than the width at the incline, so as to relieve the car of the friction of snow against its sides. The share or center cutter of the plow starts some distance back from the cutting edge and both it and the portions of the incline subjected to heaviest wear are faced with steel plates. The surfaces which come into contact with the snow at the rear of the face are long, sweeping curves. The front end of a square-nosed plow is subjected to heavy downward pressure from the snow and hence a very strong forward truck is required. One difficulty with such trucks has been the heating of the journals, due to the excessive load. To overcome this trouble the forward truck of the Russell plow is made especially heavy and of special design Each axle is provided with four journals—that is, a journal each side of each wheel—thus giving the necessary strength and ample bearing surface. The face of the plow and the exterior of the car are covered with matched yellow pine, planed smooth and shellacked. so that it presents a smooth surface. The front of the plow is provided with a draw-bar, attached to straps anchored in the framing of the plow, so as to enable the car to be coupled up in a train, when necessary. The top of the car is fitted with a raised portion for the lookout, who communicates with the engineer by means of a bell cord and directs the movements of the car.

This plow is made in three styles: a single-track plow, with a symmetrical front, throwing to both sides; a double-track plow, with unsymmetrical front, throwing to one side only; and a "wing-elevator" plow, for either double or single track. Each of these styles is made in three sizes. Figure 407 is a view of the single-track plow, intermediate size, as made for the New York Central & Hudson River R. R. This plow is 34 ft. long, 11 ft. high at the front and weighs 46,000 lbs. without ballast. The rear buffer is mounted on the end of the "power bar" and is shown in the rear view. To facilitate coupling with locomotive draw-bars of varying hights it has four pockets. The Russell plow for double track is constructed on the same general principles as the single-track plow, the only essential difference being in the location of the share or cutter, which, of course, is placed at one side of the incline instead of at the center, so as to throw all the snow to one side. The plow is

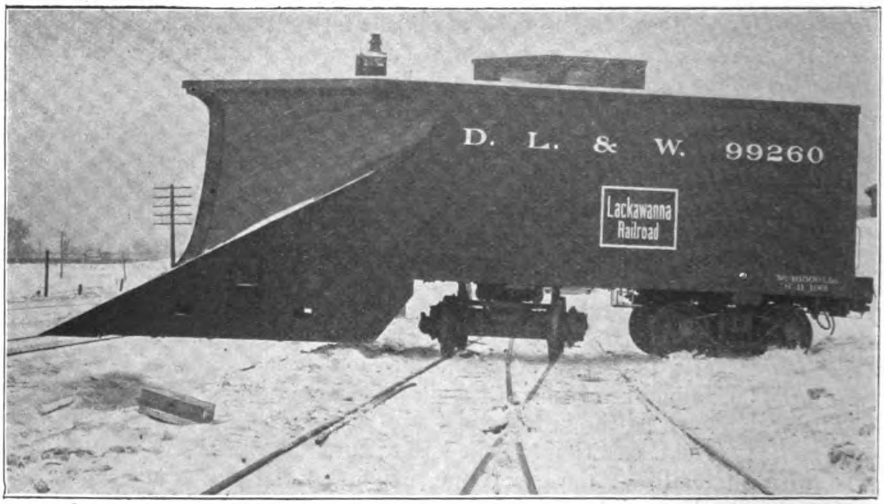


Fig. 408.—Self-Turning Snow Plow, Delaware, Lackawanna & Western R. R.

made for either right-hand or left-hand running. The usual method of clearing a double-track road is to run the plow over one of the tracks, turn the plow and return by the other track. As some double-track roads (including the Lake Shore & Michigan Southern and the Chicago & Northwestern) run left-handed—that is, the right-hand, or engineer's, side of the engine coming between the tracks instead of on the outside—the snow plows for such roads, in order to run in the customary direction of the train movements, must necessarily throw to the left. These double-track plows, if they happen to be turned the right way, are well adapted to side-hill plowing. The cutting edge of the share is 5 ft. back of the front of the incline, so that the incline is securely held down by the weight of snow in advance of the point where the side pressure on the plow begins, and there is no danger of the plow being thrown off the track by side pressure. It may also be stated that in side-hill plowing with a single-track plow, the bank side of the plow will fill up and all of the snow will be thrown to the other side, or away from the bank. One way to clear both tracks of a double-track road, and the midway at the same time, is to run a single-track plow over the track on the windward side, with the wings open, and follow behind with a side plow on the other track, opening out the wing on the lee side. In order to do this it is of course necessary to have both tracks clear of traffic.

In fighting snow the demand often arises for some arrangement whereby a snow plow may at any time be made quickly ready for use in either direction. It is sometimes the case that snow at one end of a division is deeper or more troublesome, from drifting or because of other conditions, than at

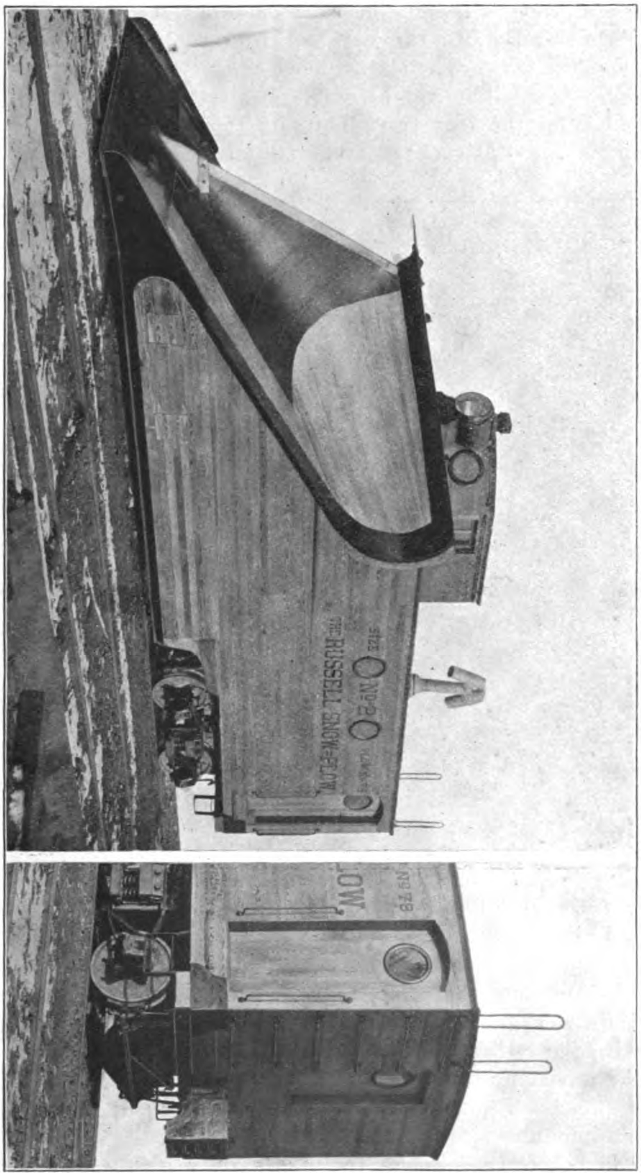


Fig. 407.—Russell Single-Track Standard Snow Plow, N. Y. C. & H. R. R. R.

the other, and in cases of this kind it frequently happens that it is desirable to stop at some intermediate point on the division and return. Such might be the case on double track, where, after having covered the district over which the snow is most troublesome, it is desired to take a crossover and plow back over the other track; or, indeed, in event the snow is rapidly drifting, it might be desirable to start the plow back over the same track, as on a single-track road, thus saving time which would otherwise be wasted in running to the nearest turntable, which would usually be at the end of the division. To meet the requirements of such a situation the Delaware, Lackawanna & Western R. R. has a push plow with a turntable arrangement self contained with the car, for turning the plow end for end at any point on main track. There is a turntable track 4½ ft. in diameter attached to the front truck of the car, and near the center of the car, which is 37 ft. long, there is a bolster with a center bearing to fit the truck, and six 8½-in. wheels arranged in a circle to bear upon the turntable track. In order to turn the plow the front end of the car is raised, by means of compressed air cylinders, to clear the forward truck, which is then rolled back under the center bolster or bearing. The weight of the car is then supported by the truck under the center, the rear truck hanging to the car body. The turntable device being located at such a point that the car body is balanced over the

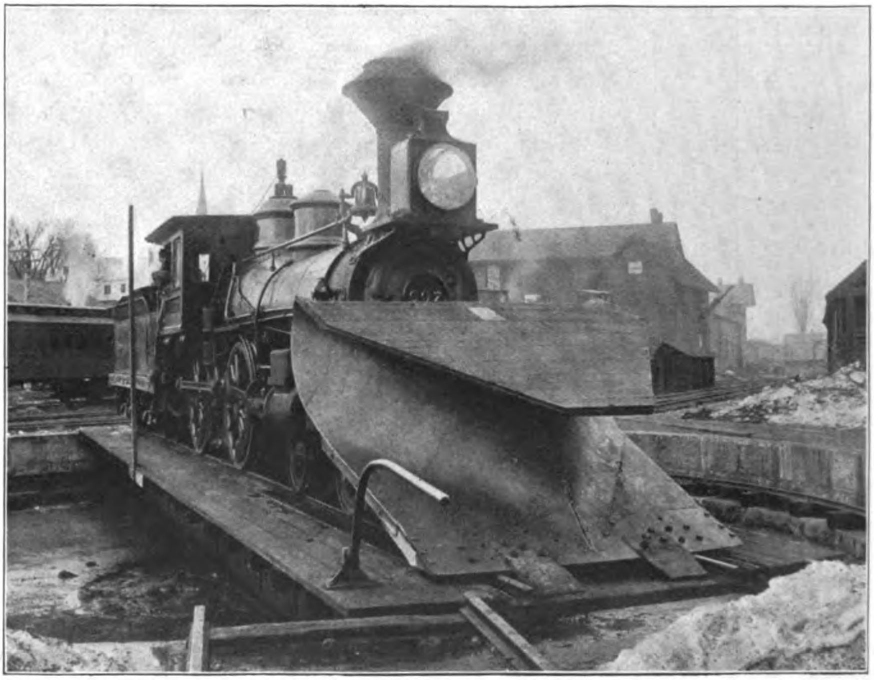


Fig. 409.—Pilot Snow Plow and Flanger, Vermont Valley R. R.

center truck, the plow is turned by pushing it around with a gang of men, three men being a sufficient force. Figure 408 is an illustration of this plow in process of turning. The arrangement for hoisting the front of the plow clear of the truck at that end is a 12-in. air cylinder on each side of the car, opposite the center of the truck. It has a downwardly acting piston which takes a bearing on blocking placed on the ends of the ties.

Pilot Plows.—Pilot snow plows, sometimes called Congdon plows, are of various kinds and sizes, ranging from moldboards of boiler plate 2 or 3 ft. high attached to the pilot of the engine, to a plow extending as high as the top of the boiler. In the latter case the steel plate face or moldboards of the plow are usually backed by a wooden frame attached to the pilot and braced against the engine frame, or in some cases the pilot is removed to give place to this frame. One fault with many pilot plows is that when the engine runs backward the moldboards will pull snow into the track, and in hard snow the moldboards are sometimes broken off in this way.

One way to overcome this difficulty is to place guard plates at the sides of the plow, in rear of the moldboards. Pilot plows are usually intended for service in snow of moderate depth, say not to exceed 4 ft., the intention being to equip all or part of the trains with such plows and keep the road clear by the frequent passing of the trains. In cases, however, such plows are made to do heavy work, the locomotive equipped with the plow being assisted by one or more locomotives as pushers. On a number of roads plows as high as the pilot are permanently attached to locomotives for the winter season, remaining on the locomotives while making their regular trips. Thus, on the Wisconsin Central Ry., all the passenger engines and about 25 per cent of the freight engines are equipped with pilot plows reaching to the top of the bumper beam, while one engine for each division has a pilot plow 8½ ft. high, or extending to the top of the smoke box, for heavier duty in emergency.

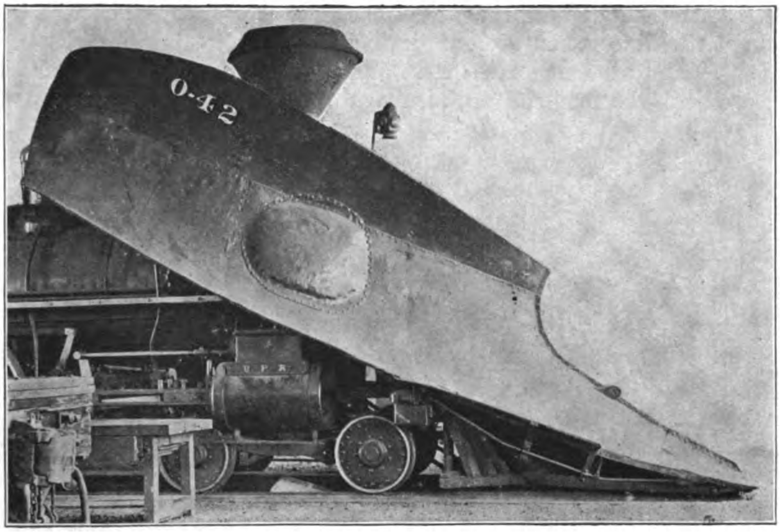


Fig. 410.—Pilot Snow Plow, Union Pacific R. R.

Figure 409 shows a pilot plow used on the Vermont Valley branch of the Boston & Maine R. R., for all except the deep snows. The plow is built of heavy framed timbers, sheathed with hard pine and faced with ⅛-in. iron plate. The plow is 4 ft. high, above the rail, at the front end and 6 ft. high at the rear end. The plow is attached to the locomotive by means of a hinge at the bottom. The hinge rod or pin extends the entire width of the plow, running through the hinge castings on either side. The abutment for the plow, on the locomotive, is arranged similarly to the old-fashioned "broom guards." The top of the plow is connected by rod and crank to an air cylinder which stands in a vertical position directly over the front axle of the engine truck. When in service the nose of the plow rests upon cast iron shoes which slide upon the rails. When not in service it is lifted from the working position by means of the air cylinder and held clear of the rails. The "cutters" or flangers consist of heavy steel plates bolted to the nose of the plow, as seen in the picture, which shows the plow in the working position. This arrangement provides for quickly replacing the flangers should they become torn loose by an obstruction. They are adjustable by means of the bolts, and when the plow is used at night they are taken off. To provide for service in the case of sudden calls the pilot of the engine is removed in the fall, and this engine is then used for switching purposes, so that it is in readiness at any time. The plow can be attached to the engine or detached from it in five minutes. The crew for operation consists of the engineer, fireman and a conductor, the engineer handling the plow. Figure 410 shows a plow attached to the pilot of a light engine of the Union Pacific R. R., which is kept in the roundhouse at Rawlins, Wyo., for service in snow of 3 ft. depth and less. For heavy work, in hard snow, two engines are used to push the plow, and in snow of the depth stated the plow is said to do efficient work.

Machine Plows.—The machine snow plow might be described as a modified type of old-fashioned fanning mill, of monster size, on wheels, with the hopper turned up squarely to the front. The pressure of the machine forward crowds the snow into the hopper and the swiftly revolving fan throws it violently through an opening high into the air and to one side, in a stream as large as a flour barrel. By adjusting the opening or exit passage the stream may be thrown to either side, as desired. The wheel in one style of machine is a propeller, similar in action to the propeller of a steamboat, and in other machines it is simply an immense screw or auger, which bores out the material crowded against it, throwing it out of the

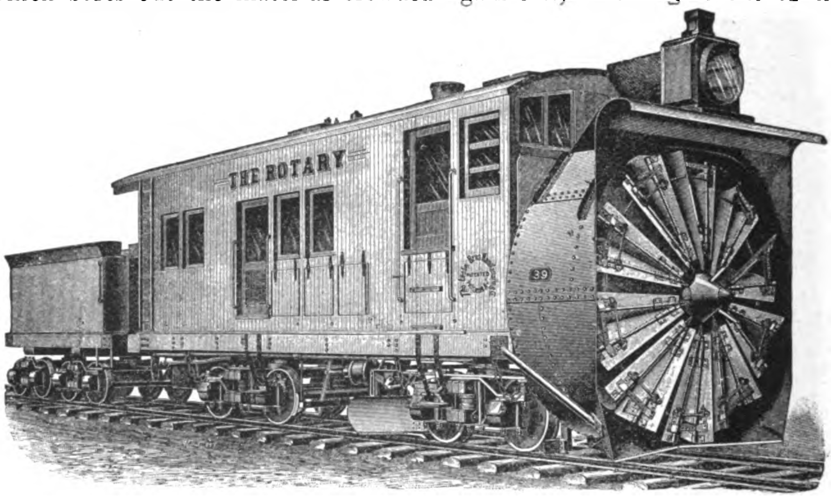


Fig. 411.—The "Rotary" Snow Plow.

chute directly or into a fan wheel. It is turned by power furnished on the machine itself, the rotary or plow portion being but the head end of a long car. The first machine snow plow to see real service was designed by Mr. Orange Jull, and was tried for the first time on April 1, 1884, in the yards of the Canadian Pacific Ry., at Montreal. This plow had a rotating wheel with cutting blades and was the prototype of the modern "Rotary." The first machine snow plow used in the United States was an improved form of this plow, and saw service in the winter of 1886-87 on the Union Pacific R. R.; but up to the year 1888 this was the only machine plow to be put to work. During the years 1888 to 1890, inclusive, machine plows were vastly improved upon and came into use quite extensively, particularly on the Rocky mountain roads. The three types which then came into use were the "Rotary," the "Centrifugal" or Jull plow, and the "Cyclone." On general principles the construction and operation of all three machines are the same, except in the form of the excavating device. They all take the form of a box car with a rotating device or excavator enclosed within a hood at the front of the car.

The "Rotary" snow plow (Leslie machine) is shown in Fig. 411. At the front of the car there is a hood formed of steel plates, with cutting edges at the sides and bottom. The width of the hood is 10 ft. and the bottom cutting edge is carried only 3 or 4 ins. above the rail. This hood tapers into a circular drum, within which the rotator revolves at about 200 revolutions per minute upon a longitudinal shaft turned by two vertical engines combining 800 horse power. At the rear of the car there is a locomotive tender to supply fuel and water. In the old form of Rotary plow (Fig. 412) the excavator consists of a knife wheel with flat cutting blades, with a fan wheel in the rear, both being attached to the same shaft and turning together. In the improved machines, however, the fan wheel is dispensed with and a new form of wheel is provided. This wheel is composed of ten hollow funnel-shaped scoops, arranged radially on the wheel. The scoops widen or flare from center to circumference of the wheel, and each scoop is open its entire length on the front side, through which the snow is taken in. On each side of the opening on the front side of the scoops there is hinged a knife or cutting blade, the knives of each two adjacent scoops being linked together, as shown, so as to automatically adjust

Fig. 412.—Rotary Snow Plow (Old Design).

themselves into cutting position whichever way the wheel is turned. The center of the wheel projects ahead of the hood, while at the circumference of the wheel the hood projects 3 ins. in advance of the cutting edges of the knives. At the top side of the drum within which the wheel revolves there is an opening with an adjustable cover, arranged so as to throw the snow to either side, as desired. The action of the wheel is to cut the snow into the scoops, from which it is thrown at high velocity, by centrifugal force. As the snow is revolved at high speed within the scoops it leaves the wheel at a tangent as it meets the opening. In order to change the direction in which the snow is thrown, as sometimes becomes necessary, in order to throw to the down-hill side or to avoid throwing the snow against the wind, the wheel must be revolved in the opposite direction. The chute through which the snow leaves the drum is just in rear of the headlight, and the cap or adjustable cover of the chute is so arranged that it can be reversed from the pilot house when the wheel is turned to throw the snow to the opposite side of the track. The pilot house is in the forward end of the cab, being partitioned off in front of the front end of the boiler. A curved deflector plate or apron is placed across the top of the hood to prevent snow from flying and obstructing the view of the pilot. In front of each forward wheel of the car there is an ice cutter, secured to the lower end of an arm of a wrought iron frame, by two bolts. This ice cutter is composed of two parts, known as the wing and the cutter. The wing projects over the rail and the cutter drops down inside the rail. Should the cutter strike a guard or crossing rail it will shear the lower bolt holding the arm to the frame, and the cutter will be deflected backward without further injury. To repair the damage it is necessary to replace only the broken or sheared bolt. It is said that this ice-cutting device works efficiently, and prevents the derailment of the car when working through drifts of snow frozen at the bottom. At the rear of the front truck the car is provided with a flanger, hung on the rear end of the frame of the truck and drawn by wrought iron arms which are journaled on the rear axle of the truck. The flanger is raised or lowered by an air cylinder operated by the pilot or lookout stationed in the pilot house. The flanger points are four in number and are the only parts which extend below the top of the rail. These parts are bolted to the bottom of each wing of the flanger with ½-in. bolts with countersunk heads, so as to be readily torn loose in case the flanger meets with an unyielding obstruction. The ice cutter and flanger are both connected by means of iron rods to cranks on a balance shaft mounted on the truck frame about midway, thus permitting both to be raised and lowered simultaneously by the air cylinder. In the operation of the plow the pilot or lookout operates the air brakes on the entire snow-plow train with an engineer's valve, in the pilot house. He also operates the flanger and ice cutter. In case the air pump on the rotary becomes disabled while the plow is in service, the flanger and ice cutter are operated by steam instead of air. The ordinary weight of the plow is 70 tons, and the length without the tender 36 ft. A later design of this machine, built for the Colorado Midland Ry., has a hood 12 ft. wide, built of ⅜-in. steel plate, and a 12-tube rotator 11½ ft. in diameter. The hood cuts a passage wide enough to permit long Pullman cars to pass around 16-deg. curves without rubbing the inside bank. The car is strongly built on 12-in. I-beam sills, and the total weight is 85 tons.

The "Centrifugal" or Jull machine snow plow consists of a heavy iron car with a hood in front, like the "Rotary." This plow was designed by Mr. Orange Jull, the designer also of the original rotary pattern, as stated. It was brought out during 1889 and was first put to service on the Union Pacific R. R. between Granger, Wyo., and Huntington, Ore., in the winter of 1889-90. The working portion of this plow consists of a cone of 7½ ft. diameter at the large end, with four spiral-shaped, curved blades of ½-in. steel, making about ¾ of a turn in the length of the cone. At the base of the cone these blades are 2 ft. wide, tapering to the apex of the cone. The cone is set diagonally across the hood, pointing to the right-hand rail—that is, the small end or apex of the cone is journaled at the lower right-hand side of the hood (looking forward) and the rear portion or large end of the cone is journaled in the diagonally opposite corner of the hood, or rear left-hand side. The cone is run at from 250 to 300 revolutions per minute by a powerful engine and the snow is discharged through the chute in the top of the hood by centrifugal force when leaving the cone, without the use of an auxiliary fan. The chute or outlet for the snow at the top is 5½x2 ft., and the opening is adjustable, so that the snow may be thrown to either side of the track. The weight of the machine is 65 tons.

The "Cyclone" snow plow was brought out during the year 1889 and did its first service on the Central (now Southern) Pacific Ry. also during the winter of 1889-90. The working portion of this plow consists of a large auger revolving within the hood upon a longitudinal shaft turned by a vertical engine of 600 horse power. This auger is $10\frac{1}{2}$ ft. in diameter at the rear portion and tapers down to a conical head at the extreme point. The auger is formed by three spiral-shaped blades of steel, $\frac{3}{8}$ to $\frac{1}{2}$ in. thick, the blades being conical in outline. Attached to the edge of each blade there is a $3\frac{1}{2}$-in. steel angle, beveled on the cutting edge. At the rear of the auger there is a fan wheel 10 ft. 4 ins. in diameter, composed of 12 blades of $^5/_{16}$-in. steel plate, turned by two engines of 600 horse power each. The hood is made of $\frac{1}{2}$-in. steel plates and is provided at the top with two openings with a swinging door between, to serve as the chute for discharging the snow. Of these three kinds of machine snow plow the Rotary or Leslie machine is the most extensively used. The manufacture of the Cyclone plow was discontinued long ago, and as late as 1904 only a comparatively few Jull plows were in service.

The ability of machine plows to handle snow of any depth ordinarily met with on railways is well established. Such plows will bore their way through a bank of snow as high as the top of the hood with all ease, and if the snow bank is much higher than the hood it is only necessary to tumble the snow down in front of the plow in order to have it thrown clear of the track. In snow exceeding 8 ft. in depth or wherever snow becomes hard packed or frozen, they are particularly in demand. For mountain districts, where snow falls very deep, and also for heavy drifts in cuts, it is the most effective type of plow. Its progress is much slower than the push plow doing ordinary open work, but nothing short of a solid mass of ice can stall it. It also throws the snow well clear of the track, whereas the push plow can not always fling the snow out of deep cuts. No road which has difficulty in keeping the track clear with push plows should be without one. In side drifts that are hard packed or mixed with sand or dirt, where it might be dangerous to use a push plow without first shoveling down the high side, the machine plow can be operated without difficulty and without leveling up the drift. These plows will throw the snow in a solid stream of about 4 ft. diameter, from 50 to 150 ft. from the track, the plow traveling at a speed which will perhaps not exceed 6 miles per hour in heavy snow and 12 or 15 miles per hour in light snow. The records of the Fremont, Elkhorn & Missouri Valley R. R. (Chicago & Northwestern Ry. system), where as many as six rotary machines have been in service at one time, show that the machine has gone through 400 ft. of snow 8 to 12 ft. deep in 2 minutes, 1830 ft. of snow $6\frac{1}{2}$ ft. deep in $3\frac{1}{2}$ minutes, 1200 ft. of snow 7 ft. deep in $5\frac{1}{2}$ minutes, etc. In heavily compacted or frozen snow of good depth the speed is one mile per hour or less.

The enormous power of the machines may be judged from the fact that in January, 1890, the "Centrifugal" plow, working between Glens Ferry and Huntington, Ore., ran afoul of a steer on the track, cutting the animal in two and throwing it out with the snow without the least impediment to the machinery. During the same winter the Denver daily papers reported a similar occurrence with a "Rotary" plow on the Colorado Midland Ry. As the story goes, a herd of cattle had taken refuge in a cut and frozen to death and eventually were buried under 15 ft. of snow. It is said that the Rotary "went right through the cut, shedding beefsteaks all over the country." These plows can work their way through heavily filled cuts where it would be impossible to lift the snow with any form of push plow, not to speak of throwing the snow out of the cut. On the switchback of the Great Northern Ry., in the Cascade mountains, before the construction of the Cascade tunnel, rotary snow plows were required almost continuously during winter time to keep the track clear. In order to avoid having to turn the plow when changing from one spur of the switchback to the other, it was arranged to have two rotaries in the same train headed in opposite directions, with two consolidation locomotives coupled between. In this manner the rotaries came alternately into service as the train moved from one leg of the switchback to the other. On the New York Central & Hudson River R. R. the rotary plow is used to widen cuts cleared by the push plow. After the push plow has been run through the cut the men throw the side banks of snow down upon the track and the rotary is then run along to clear out the cut again.

Wing Snow Plows.—A wing plow is one having extensions or wings at the sides for widening a cut previously plowed out. A very common arrangement is to attach wings to the sides of a box car or some special

Fig. 413.—Wing Snow Plow and Flanger, Vermont Valley R. R.

car and couple it on at the rear end of a train. On the Minneapolis, St. Paul & Sault Ste. Marie and the Duluth, South Shore & Atlantic roads a rotary plow is first used to clear the cut, after which a wing plow is run through the cut pulling down the snow from the bank on either side and depositing it in the track behind the car. A second trip of the rotary clears out the cut again. This wing plow is formed by constructing a heavy framework on a flat car, to which is attached, on either side a wing, opening to the front. These wings shear the snow 8 ft. from the center of the track. The purpose of widening cuts through snow is to make room for snow thrown out by flangers and to facilitate plowing out later accumulations of freshly fallen or drifted snow. The use of a wing plow in deep snow may thus enable pilot plows to take care of light snowfalls or drifting snow from that time on. Where a cut through deep snow is not widened out beyond the ordinary clearance lines refuge niches should be cut in the walls of the snow at intervals to protect workmen from passing trains.

The most approved arrangement is to combine the wings with a push plow. A good example of this kind of construction is a car built by the Vermont Valley R. R., shown in Fig. 413. The plow is 7 ft. 8 ins wide on the cutting edge and 8 ft. 2 ins. wide above the cutting edge, which is made adjustable, for flanging purposes. The car is 32 ft. long and the outside width of the car body is 7 ft., being narrower than the width of the plow, to afford recesses for the wings. The extreme hight of the car is 13 ft. 8 ins. and the hight of the plow is 10½ ft. above top of rail. The framework, especially at the forward end, is strongly built and the car is mounted upon locomotive trucks. The plow is heavily ballasted, the space under the flooring, between the sills, in the vicinity of the trucks, being filled in solid with pieces of old rail. The weight of the car is 54,000 lbs. The plow is built strong enough to stand up under work requiring three locomotives for the pushing force, if necessary. The plow is faced with hard pine, which is covered with galvanized sheet iron. Extending over the face of the plow there is a guard to prevent snow from flying against the lookout

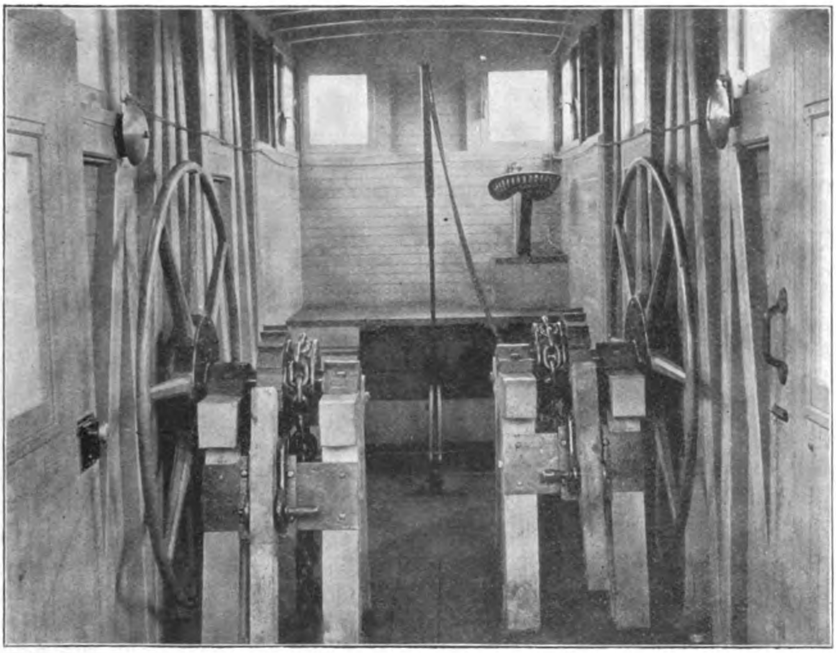


Fig. 414.—Interior of Vermont Valley Wing Snow Plow.

windows. On this guard there is placed a locomotive headlight and a locomotive bell. The wings are huge doors hung at the sides of the car and operated from within. They are constructed of two thicknesses of heavy plank bolted together, and a strip 3 ft. high from the bottom edge is faced with ¼-in. steel plate. When the wings are extended their full width they have a sweep of 17 ft. To secure firm anchorage for the hinges of the wings the sides of the car are reinforced with plank. The mechanism for operating the wings and the nose of the plow is shown in the interior view, Fig. 414. The large wheel at each side of the car operates a sprocket wheel and chain, the latter running over pulleys in a manner to pull on the end of the arm or strut which throws out the wing on the same side of the car. One end of the chain is attached to the wing direct and the other end to the end of the arm, thus affording a means for moving the wing either outward or inward. To hold the wings up to their work there is a large cast iron ratchet on the shaft of the sprocket wheel, which is engaged by a $2\frac{1}{2}$x3-in, red oak dog, which will split and save the mechanism from breakage in case the wing should meet with a solid obstruction. When the pressure against the wing is very hard it is released by striking the dog with a hammer. In case the dog becomes split it is reversed on its supporting pin and this expedient may be resorted to until all four corners become split off. The seat for the lookout or pilot appears in the right-hand corner. In front of the seat there is a conductor's valve, for operating the air brakes, with which the car is equipped, for use in emergency, and a cord runs to the locomotive bell in front. There is also a cord running to an alarm bell in the locomotive cab. The signals for operating the wings are delivered by bells, one bell for each wing. These bells have different tones, to avoid mistakes when it is desired to operate only one of the wings. The long lever in the center of the car adjusts the movable nose or cutting edge. The lifting mechanism consists of roller-ended struts operated by the lever. The movable point or nose is a heavy cast

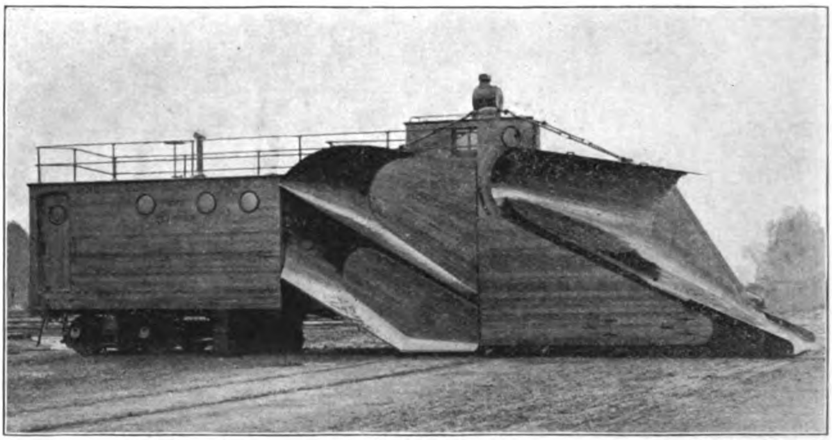


Fig. 415.—Russell Wing-Elevator Snow Plow, C. & W. M. Ry.

iron plate. For flanging out the space between the rails there is a 1-in. steel plate bolted to the nose casting (Fig. 413), and the side cutters consist of $\frac{5}{8}$-in. steel plates bolted in the same manner. To facilitate adjustment the bolt holes of these cutter plates are slotted. The cutter or flanging plate between the rails reaches 3 ins. below top of rail and the outside plates reach as low as top of rail. When the nose is dropped for flanging it bears upon shoes which slide upon the rails. The plow is usually operated by the roadmaster with the assistance of four men. When operating on double track it is usual on the first trip out to run the car at high speed, with both wings wide open, throwing the snow on the inside clear across the other track. On the return trip the plow is run slowly, with only the right-hand or outer wing open. The plow has given satisfactory service in snow 8 ft. deep and in bucking hard packed snow in cuts.

The Russell "wing-elevator" snow plows are heavily built and extensively used. Figure 415 shows a plow of this type, with a flanger, built for the Chicago & West Michigan branch of the Pere Marquette R. R. The largest plows of this design are 44 ft. long, 13 ft. 10 ins. high, 10 ft. 1 in. wide at the front and 16 ft. 4 ins. in outline width with both wings open. The plow is carried upon two 4-wheel trucks, the front truck being of special design, with eight journals—one each side of each wheel. The weight is 35 tons. The wing feature of the plow consists of a heavy framework constructed of double courses of oak plank and hinged to a post at either side of the car. The outer face of each wing is formed into two concave portions or chutes, called "elevators," slanting upward at an angle of 30 degrees with the horizontal, so that when the wing is swung into working position the snow is carried outward and upward. This wing is hinged at its front end and the rear end is stayed by a truss rod running over the top of the post, as shown. When the wings are not in use they hang within recesses at the sides of the car. They are operated by a man in the car with hand-wheels and bevel gear, at the command of the lookout, who has a gong and code of signals. The wing can be forced out and held at any point within the limit of its movement, and the wing on one side of the car can be operated independently of that on the other side. The action of the wings is to cut under the snow and lift it, throwing it 30 to 60 ft. away, according to speed of the train, instead of crowding the snow to one side, which would be difficult if the snow was packed hard. The car is also fitted with a flanger, which is located just forward of the rear truck, and is described further along.

Snow Flangers.—A flanger is a device for holding blades in position to throw snow out of the track as the contrivance is trailed along. The blade scrapes the top of the rail or very near the top, and is notched down so as to scoop out 2 or 3 ins. below top of rail inside the track. On roads where the nuts of the track bolts are placed on the gage side of the rails the flanger blades must be notched with offsets to clear them. These blades may be placed on the pilot of an engine or be trailed behind a caboose. It is more usual, however, to rig them under a flat or box car. The blade is run slantwise to the rail, with the inner end ahead, and must be raised when approaching switches, guard rails, cattle guards, wooden insulation splices and road crossings—generally at a signal by whistle from the engineer. The apparatus for raising it may consist of a system of levers, block and tackle, windlass, or a pneumatic cylinder and piston, the supply of air being taken from the train pipe through extra auxiliary reservoirs and check valves, so as not to set the brakes. Another way in which flangers have been operated is to cut out the air brake cylinder under the tender and other cars in the train, thus rendering the brakes inoperative for the time being, so as to permit the flanger to be worked by the engineer, from the engine cab. The flanger usually consists of two parts —moldboard and knives. The knives are usually attached to the moldboard in such a manner as to be easily torn loose when meeting with an unyielding obstruction. In rear of the flanger there should be a wire broom to clear the rail of snow dug up by the flanger. The principal advantage in flanging is to make room for the wheels to crowd out accumulations of freshly fallen or drifted snow. When wheels cut their way through snow a rut is formed along each rail, and eventually the snow at the sides of these ruts becomes hard packed, and sometimes frozen into ice. When snow drifts these ruts become quickly filled, and since, owing to the conditions, the wheels cannot readily throw the snow out or crowd it aside, a good deal of it must go under them, making traction difficult and increasing the train resistance.

One of the best known snow flangers is the Priest device, designed by Mr. A. F. Priest, master mechanic of the Duluth, Missabe & Northern Ry. The cutting blades and deflecting plates are attached to a cross bar supported upon the front boxes of the engine truck by extending the outside equalizing bars. It thus works but a few inches in front of the forward wheel, or just in rear of the pilot, in which position the depth of cutting is not affected by the teetering motion of the engine on rough track, and the blades cannot move across the rails on curves. The flanger is operated by an 8-in. air cylinder placed under the running board and connecting by means of a reach rod, and is controlled by a special three-way cock in the cab, within reach of the engineer, who can instantly raise the blades or knives to clear crossing plank, guard rails, frogs etc. The backward thrust of the knives is received against the forward truck boxes. The cutting knives are $^5/_{16}$-in. steel blades and each knife is held to its wing support by a pin and bolt. In case the knife becomes broken or bent it may be disengaged by the removal of only one bolt. The knife is held 1 in. above the rail and $1\frac{1}{2}$ ins. clear of each side of the rail head; so that it will not remove torpedoes placed for danger signals. It makes a cut 12 ins. wide by 2 ins. deep inside the rail and 12 ins. wide by $\frac{1}{2}$-in. deep outside the rail. A safety latch is provided for holding the cutting knives in their raised position without continued use of the air. The Temple flanger is fitted to locomotive cowcatchers. The Russell flanger, already referred to, is shown as Fig. 416. The lower edge or knives of the flanger are separable from the moldboards and are easily replaced in case of breakage at guard rails or crossings. The knives drop $2\frac{1}{2}$ ins. below top of rail and are operated either by compressed air cylinders or hand levers inside the car. The flangers shown in Figs. 409, 411 and 413 are described in connection with the plows with which they are combined.

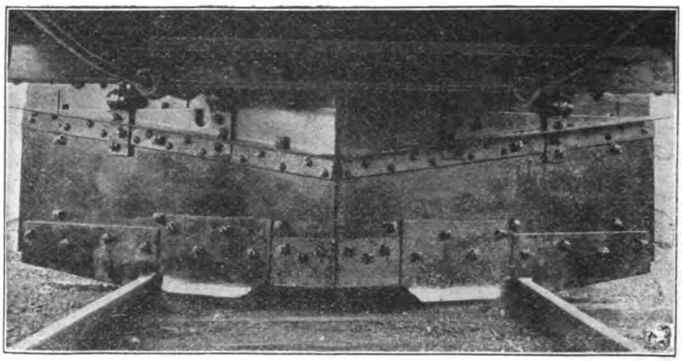


Fig. 416.—Russell Snow Flanger.

The Union Pacific and Oregon Short Line roads have a number of four-wheel flanger cars of short length, one of which is shown in Fig. 417. The car is 11 ft. long and is loaded down with old car wheels and other scrap iron to a weight of 30,000 lbs. The flanging devices consist of a set of knives and a moldboard of boiler plate on each side, the latter to lift the snow and throw it out of the way. The flanger knives consist of a steel plate 10 ins. wide by $1\frac{1}{2}$ ins. thick, each side of each rail, attached to a rock shaft made from an old car axle, which is supported crosswise the track upon braced hangers strongly stayed to the back end of the under side of the car framing. Safety chains suspended from the car prevent the knives from being dropped too low. These knives can be raised and lowered either by hand, with the lever attachment shown, or by air from the train pipe controlled by the engineer through the brake valve in the cab. In operation the flanger car is hauled behind a locomotive, and to indicate to the engineer whether or not the flanger is working, there is a target on a staff in connection with the shaft which carries the flanger knives. Another contrivance sometimes used for flanging track on this road is a

Rodger ballast spreader car (Fig. 43) with the ballast plow removed and a snow flanger substituted in its place. In winter, while there is no other use for the spreader car, the flanging knives remain attached to the car, ready for service. The Chicago & Northwestern Ry. uses a type of flanger designed for double track, to throw all the snow to one side. The flanging arrangement is on the moldboard style, something similar to the one shown in Fig. 417, and there are three of them disposed in tandem, diagonally across the track, under a box car. There is a flanger on each rail and one between these two to scoop out the middle of the track, the flanger on the right-hand rail being in the advance (for left-hand running), with the middle flanger just to the rear and to one side of it, while the flanger on the left side is just in rear and to one side of the middle flanger, which scoops out the track 1 in. below top of rail. Each of the outside flangers is notched at the rail and bears upon the rail by a sliding shoe. The flangers are attached to rock shafts operated from the car above. On each side of the car there is a projecting box with a window in the front side to serve as a lookout.

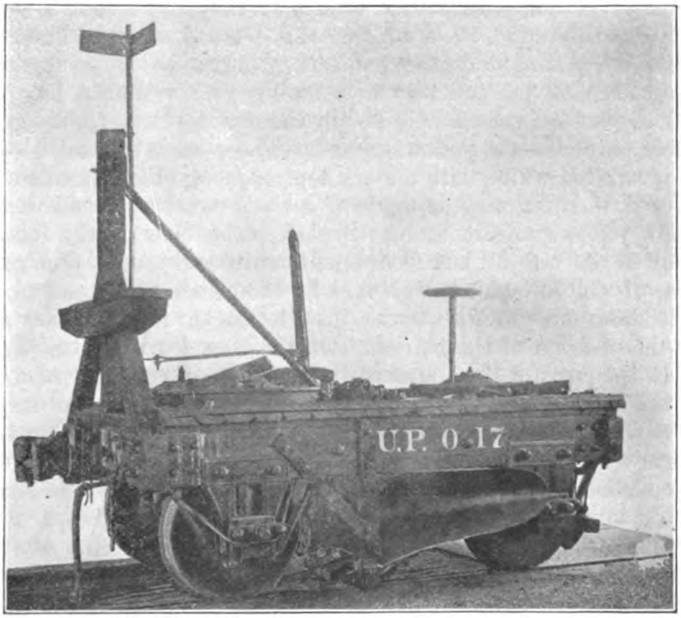


Fig. 417.—Snow Flanger Car, Union Pacific R. R.

For handling snow and ice in the Adirondack mountains the New York Central & Hudson River R. R. has a specially designed strongly-built car of the freight caboose style, with the lookout centrally located on top, as in Fig. 408. Under the car there are two pilot-shaped plows arranged for service in either direction. Each of these plows consists of vertically adjustable plates backed by heavy cast iron knees or brackets rigidly suspended from the car sills. The flanging plates are notched to plow out deeper than top of rail on the inside of the track, and they are lowered and raised by a 10-in. air cylinder, pressure being supplied by the air brake system through storage reservoirs on the car. At the sides of the car, on the flanks of the flangers, there are narrow wings hinged at an incline, to remove snow to the desired clearance for any kind of equipment. These wings are operated by an air cylinder lying horizontally on the car floor.

The operation of the flangers and side wings is controlled by air valves in the pilot house. The detail drawings are shown in the Railway and Engineering Review of March 15, 1902.

Each year before snow falls the section foremen should see that snow plow markers are set in advance of any obstruction which will interfere with the operation of the flangers. On some roads there is a fixed date on or before which all the markers are required to be up. Markers are usually placed on the engineer's side, except on some double-track roads, where it is occasionally the practice to place them across the other track. As no snow is thrown toward that side a clear view is always obtained, except when passing a train on the other track, so that, after all, the practice has its objections.

A common form of snow marker is one or two pieces of fence board 18 to 24 ins. long nailed to a post set some standard distance from the track, like 6 ft., and 30 to 50 ft. in advance of the obstruction. It is common practice also to nail a marker board about 3 ft. long well up on the first telegraph pole in advance of the obstruction. In the largest practice it is not considered necessary to paint snow markers, and they are removed in the spring and saved for future use; otherwise they are liable to be stoned by the boys and knocked off or broken up. On a few roads, however, particularly in New England, the markers are got up in good shape and painted, and remain permanently in place the year around. The Vermont Valley R. R. uses a 24x8-in. board with the corners cut off, having a 7-in. black circle painted on a yellow ground. The post is square in cross section and is painted white, with a black top. Among other conspicuous signs that are used, mention may be made of a black panel with two white bull's eyes, and a yellow panel with black spots. The New York, New Haven & Hartford R. R. uses a black board with white stars, on a post consisting of a piece of old rail painted black. If the panel gets knocked off, the black post shows up prominently against the background of snow and still indicates the position of the marker. On the New York Central & Hudson River R. R. the post for the standard snow plow marker is 2x4 ins., pine, 12 ft. long, set 4 ft. in the ground, 7 ft. from the rail. Up to 4 ft. above ground the post is painted black, and above that, white. The sign is a ¾-in. board 8 ins. wide and 2½ ft. long, painted black with a white margin. The board is nailed to the post at one end, so as to stand out at one side of the post, at the top of the same, and it points diagonally upward and away from the track at an angle of 45 deg. with the post. The ends of the board are cut off vertical.

The exact limits from the rail and below top of rail within which any object would constitute an obstruction to the flangers, should be made known to the section foremen; and any obstruction that is not necessary to a sufficient purpose should be removed. Badly rail cut ties which project high enough to be struck by the flanger blades should be adzed down. Some roadmasters keep on file a list of all obstructions to the flanger, and this list is revised from time to time as changes are made in the track, the section foremen reporting such changes at the time they are made. The list is always carried on the flanger car and consulted when running after dark. When the headlight does not give entire satisfaction this list is found to be a great convenience. It is also necessary to watch for and remove obstructions which might interfere with the operation of snow plows. At grade highway crossings the material for some little distance outside the rails and between the rails should be leveled down to the top of the rail; on the inside of curves it should be made somewhat lower, owing to the elevation. Where side-tracks turn out from the inside of curves the lead rail from the switch and the rail at the heel of the frog should run low enough to clear the nose of the plow as far as it extends laterally. In anticipation of the use of a wing plow all unnecessary obstructions should be kept cleared away from the track the required width, and a plow should be run over the road in the fall, with the wings open, so as to see that everything of the kind is clear before winter sets in, and to take note of bridges and other structures or obstructions which the plow will not pass with the wings open.

Snow Plow Work.—Outside of mountain regions, or wherever the snow fall is normal, and where drifting into cuts is not bad, snow is most quickly removed by a push plow, or "wedge" plow, as it is sometimes called. The pushing force required will, of course, depend upon the depth of the snow and its compactness. It is usual, however, to start the plow out with two locomotives to do the pushing, with a third locomotive following in the rear, commonly called the "drag-out," to assist in extricating the plow and pushers in case they get stuck in a cut. Some companies forbid the use of more than two locomotives with a push plow, on the theory that in case of derailment of the plow at high speed the great momentum of a number of locomotives is liable to cause a dangerous wreck. On the other hand, some companies favor the use of three or four and sometimes five locomotives, the idea being that with this number it is not necessary to run at high speed in order to push through a cut or heavy bank of snow, since the large capacity for traction will enable the plow to do its work at a moderate pace, thereby reducing to a minimum the ill effects of derailment, should one occur.

While a bad snow storm is in progress it is best not to start out the heavy freight trains, or at any rate the trains that are sent should be of short length. It is better to have trains in the yards than to have them stalled out on the road. In districts where the snowfall throughout the winter is frequent, it is a good plan to sheath the pilots of the locomotives to within two or three inches of the rail. Such provision will enable the regular trains to make their own way through 2 or 3 ft. of snow, and in this way the road can, in many instances, be kept open without a special plow. At any rate when snow is falling fast it may accumulate as deep as 2 ft. soon after the plow has passed, so that pilot plows are to be recommended in any event where snow is particularly troublesome. On the Chicago, Burlington & Quincy Ry. strips of wood are nailed in between the bars or slats of the pilots, so as to form a solid face or surface. It is not always best to hold the plow back waiting for the storm to stop, lest it may get the start of things. As soon as the depth of the snow begins to look threatening or as soon as it begins to drift, the plow should not wait any longer. Some roads make it the practice to run the plow continually during snow storms, after the snow once becomes deep enough to plow off. In starting out, the heaviest, best steaming freight locomotive should be taken. It should be coupled to the plow short, leaving little or no slack. Rather than use a bar coupling a switch engine should be taken or else the pilot may be removed from one of the road engines. The same precaution applies to additional engines which may be sent along as helpers. It is well to carry a piece of steam hose for heating water in the tender tank, so that snow may be melted as a water supply if need be. Water should be taken at every tank passed whether needed at the time or not. A car-load of coal should be carried next the tender of the "drag-out," the work-train boarding car and caboose, and the work-train crew, supplied with scoop shovels and some sharp picks. No flanger car need be run until after the track is once cleared. It is best, however, to run the wing plow early, while the snow is soft, and herein lies the advantage in having the wings combined with the push plow; otherwise it may be hauled by the "drag-out." In snow of moderate depth the wings of a push plow may be opened out part way or perhaps to full extent on the first trip over the road, but in deep snow it may not be practicable to open them out fully until making the second trip: this is a question of motive power. At the most there need be but four cars besides the locomotives and push plow. All section foremen should be under instructions to keep watch of snow accumulations in time of storms and report early by wire to the roadmaster the condition of things along their sections, as far as they can ascertain. If, then, before starting, it is known that the snow along any part of the division is exceedingly deep, or that cuts are badly drifted; or if the wires are down, so that information cannot be had, the third locomotive or "drag-out," already referred to, should by all means follow, hauling the train and hands, the first two handling simply the plow. It is best to have these two engines coupled together, whether both are needed constantly or not, especially after dark or while snow is falling thick. Cars should never be placed between two engines which are pushing a snow plow. If all the engines are used in making a run at a bad cut it is well to cut the train loose and hold it back until the cut is cleared, so that there will be no possibility of the whole train getting stuck in the cut.

In plowing snow where the track is not raised much above the surrounding level the train should be run at considerable speed, so as to throw the snow a good distance and scatter it. In such places it is undesirable to pile the snow up at the side of the track, as if the snow drifts it will settle on the track as high as the side heaps. The plow will not usually find difficulty except at cuts. Here, if the snow be deep, the engine or engines and the plow back up and take a run at it, striking at good speed; hence the term "bucking" the cut. If they fail to go through, the plow, and usually one or all the engines, will be stuck fast and unable to get either way until shoveled out by the crew. Before striking the cut the man in charge must make sure that no one is working in it. No men should ever work in a cut filled with snow unless there is a watchman posted on top to warn them of approaching trains; but the whistle should nevertheless be sounded before entering the cut. If, upon approaching a drifted cut, the appearance of things is not entirely satisfactory, it is usually best to stop and look the cut over. If the snow at the mouth of the cut is shallow and compact or frozen it should be shoveled away until a depth of 3 ft. is had, on the leaving as well as the entering end of the cut. If the wall of snow at the entrance is hard, it should be undercut. The hardest snow is usually found at the ends of the cut. Diagonal drifts across the mouth of the cut, especially if the snow is mixed with sand or dirt, are the most dangerous, and before striking such a drift its face should be squared up. Ice in the cut may be discovered by probing through the snow with a bar or by sinking test pits.

If the plow cannot be got through a cut after repeated attempts, or if the bottom is frozen into ice, such that the plow will leave the rail, resort is sometimes had to hauling out the snow in blocks, with locomotive and switch rope. The snow is cut into blocks about 10 ft. square, by shoveling around in trenches. The switch rope is attached to the block by running it around near the bottom, placing short pieces of board at the corners to keep the rope from cutting in too deeply. Another way of getting through a hard cut has been already described; that is, by shoveling out sections of the snow at intervals. Such preparation is frequently completed by the section men in advance of the arrival of the train. If the cut is deep the snow must be handled over several times, perhaps, before it can be got out of the cut. The usual method is to arrange the men on benches, or ledges cut in the snow, each shoveler passing the snow on to the next shoveler above, and so on—a slow and laborious process.

Engineers who push snow plows should be men of good judgment, willing, able to handle their engines to advantage, and not in the least timid. Only judgment gained from experience can teach men what would be a reckless speed under any given circumstances. A speed too slow will frequently be the cause of getting stuck. It is work always attended with more or less danger, but it must be done with decision and firmness, else poor success. The roadmaster or man in charge must needs be the responsible party, and he should therefore not shrink from taking his post where the danger is. He should not accuse an engineer of timidity when he is afraid to ride with that engineer in the cab. In handling push plows the flying snow usually obscures the vision of the engineer, so that, in the movement of the train, he must be guided by signals from the pilot on the plow. Such signals are usually given by bell and cord. It has sometimes been the practice to use the locomotive whistle as a means of signaling the engineer, the pilot on the plow having a line running to the whistle for that purpose. Whenever such a system is used it should be the understanding that the engineer must do no whistling at all, for if he should the pilot would have no way to signal him while he is blowing. The plow should be equipped with a conductor's valve, for applying the brakes on short notice, and also with a locomotive bell to warn people to get off the track.

A difficulty often experienced is the inability to see ahead from the plow, on account of the blinding effect of snow thrown up by the plow, or by snow sticking fast to the lookout windows. It is usually an advantage in this respect to look ahead from the windward side, and alcohol may be wiped over the glass to prevent snow from sticking. Use is also made of portable bay windows, to some extent. Of these there are two different styles, namely V-shaped and box-shaped, and they are pushed out of a hole in the side door, or in the side of the car. Another scheme that has been put into practice on several roads is to extend a long box-like peep tube forward from the lookout window at each side of the front end of the plow car. These tubes are about 12 ins. square in cross section, are made of boards, and extend ahead of the plow or far enough to be ahead of the snow thrown up by the plow.

After the train with the plow has got over the road it should start back with the flanger, if the storm is over by that time. It is, of course, an advantage to have a flanger on the plow, as then both plowing and flanging may be done simultaneously and a clear rail may be made for the engine pushing the plow. Where the plow is not so equipped it is frequently the practice to couple a flanger car on behind the engine or engines that are pushing the plow. It is a good plan in any case to do the flanging early, while the snow is soft. If a thaw comes and the snow next the rail suddenly freezes into ice, it cannot be flanged with the machine, but must be dug out with pick and shovel. The stretches of track missed in lifting the flanger at the marker boards are cleaned out by the section men. On the way back it is well to run through all side tracks with the plow, so as to save section men the work of cleaning them out. Necessary repairs to snow plows should be made before they are put away for the summer, else the matter may be forgotten and left until snow begins falling again. Snow is usually most troublesome to roads not prepared for it, as is instanced every few years by blockades in the East when snow falls to a depth of 4 or 5 ft.

CHAPTER XI.

MISCELLANEOUS.

151. Fence.—In nearly all the states railroad companies are required by law to fence in their tracks. As applying to unimproved or unenclosed lands, the law in some cases is modified or made inapplicable where the need of a fence is not shown. Thus, the obligation of the company is sometimes determined by the railroad commissioners of the state; or in other instances, and in well settled districts, often, the owner of land adjoining the company's right of way must first enclose his land with fence on all boundaries except that of the right of way, before the need of a fence along the right of way is supposed to exist. In their specifications or terms the fence laws of the different states are almost as varying as the number of states, except in the one particular—that the whole expense of building and maintaining right-of-way fences must be borne by the railroad companies. Failure to comply with the law usually places the company liable to heavy fines, which in cases are made accumulative; or for the market value of stock killed, or double the market value; or for the single or double appraised amount of injury to stock done by trains; or for injury received from an illegal fence; or for crops destroyed by stock gaining ingress over the company's right of way; and in other instances failure to provide fence makes the company liable for the actual cost of the fence when built by the adjoining landowner, or for a certain price per rod of fence so built, with usurious rates of interest until paid.

In most of the states the maintaining of a legal fence and cattle guards in good condition releases the railroad company from payment for damage to animals getting on the track through the owner's negligence. The laws of some states also provide that where abutting landowners are under contract with the railroad company to keep up the fences, the latter cannot then be held liable for killing or injuring animals which get on the track or right of way, except where such killing or injury is willfully done. In view of such enactments it behooves the railroad company, when building fence, to conform to what constitutes in the state a legal fence, whether such be compulsory or otherwise. It is important to have it everywhere the full legal hight, for the slightest variation from this requirement might have great weight with a jury. Although there is no fence which can be constructed at a reasonable cost that will hold certain unruly animals, yet if the law does permit a choice or any improvement on the legal fence it will generally pay the company to build only the best—making it as nearly "bull-proof" and "hog-tight" as a reasonable expenditure will permit. Exemption from payment for animals killed or injured should not beget with the railroad company an indifference as to whether or not animals shall be kept from trespassing the right of way. An animal struck while lying in the track, or by a slow-moving train, has often thrown the locomotive from the track and damaged the railroad company more than the cost of right-of-way fence for half a division.

A fence 4½ ft. high comes nearest to the legal fence in the majority of cases. One or more of such kinds as board, wire, part board and part wire, worm fence, and some others, are allowed in cases, but the wire, or part board and part wire, nearly always. Generally considered, barbed wire is the best material for a railroad fence. It is cheap, reasonably efficient and durable. It cannot be burned, or, at most, nothing but the posts can, and fire cannot travel along it as it can along board fence. It catches less drifting snow than a board fence and is less favorable to the growth of weeds. The chief objection to the use of barbed wire is the fact that it will injure stock if the animals get astride of it. If a board or rail be used for the top of the fence, however, so that the animals can see the fence in the night, there is but little danger of severe injury to stock. On this account the combination part wire and part board fence is well liked, and sometimes two top boards or a top board and cap are used. For a top rail a 2x4-in. scantling, mortised into the posts, is commonly used, but split rails are more durable. Split chestnut rails mortised into the posts are used a good deal in the East, and they last a long time. The top board or rail is also useful in another way, in that it serves as a brace to keep the posts properly spaced.

Touching now a point just merely mentioned above, it is not always desirable that right-of-way fence should hold drifting snow; as for instance, on level ground, where there is no liability that the track will be drifted, a board fence might cause the formation of snow banks which would extend to the track; while with track in a cut, where drifts are liable to form, the board fence, if at the proper distance, may be made to answer for a snow fence as well as a line fence. The same applies to stone fence, which is used in some parts of the country where stone is plentiful and convenient to the location. The proper hight for a stone wall fence is about 4½ ft. It will not rot or burn down, and when it is well built but very little work is required to keep it in repair. It is also an absolute stop to small animals.

Fence Posts.—Posts for fence should be of durable wood, like white or red cedar or chestnut, and the bark should be removed. When the bark is left on it hastens decay of the post, and in dry weather it increases the liability of catching fire. Locust is very good, but generally scarce, and white oak is quite durable. The life of a fence is in its posts. The bottom or buried portion of the post can be preserved either by charring the outside or dipping it in hot coal tar, and a small heap of stones placed around the post will have a tendency to keep back the weeds and afford it some protection against fire. On some roads it is the practice to reverse the posts after the bottom part becomes considerably rotted in the ground. In this way the bottom can be made to last until the entire post is about gone. The liability of wooden posts to burn and the growing scarcity of timber in some quarters have led to the use of metal fence posts to a considerable extent. It is to be remarked to the credit of metal posts that they are, or ought to be, more durable than wood, they are not lifted out of the ground when overflown by the rising of streams; and grass, weeds and rubbish along the fence can be burned without injuring the posts.

The International steel fence post is tubular in form, tapering slightly from bottom to top, and is rolled from a sheet of cold metal (No. 16 gage), so that an open seam remains. The 7-ft. post is 2¼ ins. in diam. at the top, 3½ ins. in diam. at the bottom and weighs 13 lbs. The post is driven into the ground with a wooden maul, the blows being received upon a driving cap placed on the top of the post temporarily while it is being set. As the post is driven it spreads open at the bottom and thus takes a form well suited to resist being pulled up. After the post is driven the top is compressed by a pair of tongs and a permanent cap is slipped on. Holes are punched at proper intervals for the wires, which are held by long staples passing through the post. The end post is braced by a piece of gas pipe fitting against the post by a collar, or by stay wires anchored to a stone or piece of timber buried in the ground. The Kokomo steel fence post is an angle bar of V-shaped section, with a spear-shaped point reinforced by a cast block fitting into the 60-deg. angle of the steel bar. Just beneath the surface of the ground there is a 9x3-in. breast plate riveted to the post to resist the sidewise pull. The post is set by driving and the wires are fastened with staples secured in holes punched through the angle of the bar. The end and corner posts are made of 3-in. heavy angle steel and are braced by a truss formed by two $1\frac{1}{2}$x$\frac{1}{2}$-in. pieces of steel $7\frac{1}{2}$ ft. long with spools between. The bottom of the post is riveted to a cast iron anchor plate 10 ins. square and $\frac{1}{2}$ in. thick, while near the surface of the ground there are two breast plates 4 ins. wide and 20 ins. long set at right angles to each other. The total weight of the 8-ft. end or corner post is 105 lbs. The Avery post is semicircular in section, tapering from bottom to top. Near the bottom there are upwardly pointing prongs or barbs stamped out of the

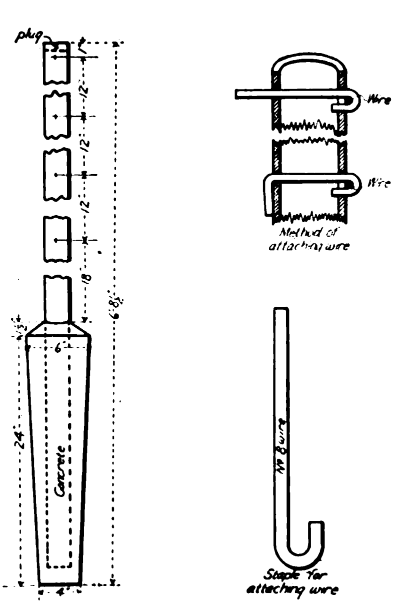


Fig. 418.—Boiler Tube Fence Post, B. & M. R. R. R.

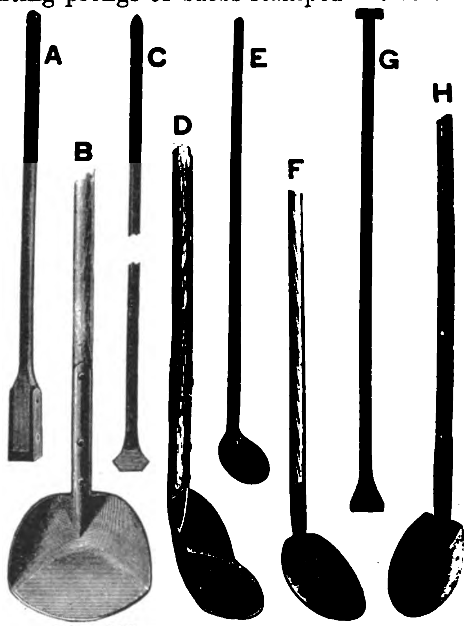


Fig. 419.—Tools for Setting Telegraph Poles and Fence Posts.

post to give it firm anchorage. The Mathews steel fence post is Y-shaped in section, with legs $1\frac{3}{4}$x$\frac{1}{4}$ in., and is securely attached to a piece of vitrified sewer pipe 6 ins. in diameter and 12 ins. long, for setting in the ground, as shown by Engraving *C*, Fig. 427. In setting the post the dirt is tamped both inside and outside the pipe, and the bottom of the pipe has a rim about $2\frac{1}{2}$ ins. wide which prevents the pipe from being pulled up. The end and corner posts are made heavier, of T-shaped sections $2\frac{1}{4}$x$2\frac{1}{4}$x$^5/_{16}$-in., attached to a piece of sewer pipe 10 ins. in diameter and 2 ft. 4 ins. long. The post is set $3\frac{1}{2}$ ft. deep and is braced by an angle bar footing against a stone in the ground.

The use of steel or iron for fence and sign posts is now generally in combination with a base of brick, terra cotta, vitrified clay or concrete moulded about the foot to give the post sufficient bearing in the ground, and protect it from corrosion. Some steel shape, like an angle, a "T," a channel or an I-beam section, or a tube is commonly used, and as for the base or butt there are many patented devices. The Climax fence post has a base of hollow vitrified and glazed fire clay, square in cross section, with ribs on the corners. In this there is a high-carbon steel angle set with cement. The "Durable" post is a combination of wood, iron and cement In the cement butt, which is 26 ins. long and 4 ins. square in cross section, are embedded two iron straps about 2½ ins. apart and projecting about 8 ins. above the top. Between these straps is bolted a painted oak post, which can be renewed without digging up the butt. The "ravine" pattern, designed to withstand the upward pull of fence wires stretched taut across a ravine or other depression, has a butt which widens out toward the bottom like a pyramid. It is to some extent the practice to mould the butts of combination concrete posts in the ground. A post hole is dug and filled with freshly mixed concrete, and into this the post is driven and the concrete permitted to set. As soon as the concrete hardens the post is firmly embedded without tamping. One scheme when setting posts in this manner is to sink a wooden stake into the concrete, and after the latter sets an iron or steel post is screwed into the stake. When the stake rots it can be pulled out and a sound one driven in its place.

The Burlington & Missouri River R. R. has made extensive use of combination fence posts by utilizing discarded boiler tubes, which are a staple scrap article with railroad companies. The post is constructed by moulding a concrete butt 25½ ins. high, 6 ins. square at the top and 4 ins. square at the bottom, around one end of a section of boiler tube 6½ ft. long. For line posts 2-in. and 2¼-in. tubes are used, and for corner posts and braces 2½-in. tubes. The corner post has a concrete base 10 ins. square and 6 ins. high, surmounted by a mass of concrete 6 ins. square and 24 ins high, the bottom part thus forming an anchor to prevent the post from being pulled out. At the foot of each brace piece there is a concrete pyramid 10 ins. square at the base and 21 ins. long, to afford bearing for the brace in the ground. The details of the line post are illustrated in Fig. 418. To protect the post from rust at the surface of the ground, the top of the concrete butt is sloped down for 1½ ins., so that dirt will wash down and keep from contact with the iron. The concrete is composed of one part cement, three parts of sand and three parts of screened crushed stone in sizes from that of a grain of corn up to a walnut. The posts are made in batteries of 48 moulds each. Before the concrete base is put on the tube is filled with mortar made of cement and sand, and then plugged at the top. This filling serves to stiffen the tube and keep it from rusting on the inside. After the post is made the iron is coated with a hot mixture of pitch and gas tar. The company has a plant at Lincoln, Neb., worked to a capacity of 150 posts per day, produced by the labor of about 4¼ men, on an average. Since 6000 to 8000 boiler tubes are scrapped each year, and as this material is of but little value as scrap iron, the posts can be produced relatively cheap. The cost varies from 16 to 19½ cents per post, as against 12½ cents for red cedar and 16 or 16½ cents for oak posts. The wires are held to the post by staples running entirely through the post and clinched on the back side. The details of the design of the post were worked out by Mr. T. E. Calvert, general superintendent. A source of extraordinary expense before these posts were used was the loss of wooden fence posts by prairie fires. It was estimated that an average of 10,000 posts were lost annually from this cause, as experience showed that more than half of the wooden fence posts along the line were destroyed by fire during the natural life of a wooden post.

Building Fence.—Wooden posts should not be set by driving, because such method necessitates sharpening the post, and a sharpened post is much more liable to be heaved up by frost than a post with a squarely-cut end at the bottom. In sharpening a post for hand driving it is necessary to hew it down to a long point, and the large amount of material cut away shortens the life of the post, as there is then less timber at the bottom of the post to resist decay. In the prairie states small pile drivers built on wheels have been used to some extent for driving fence posts. When thus driven a blunt point answers the purpose sufficiently well and is better for the fence.

A common length for fence posts is 7 ft. and the usual depth for setting the post is 2½ ft., but 3 ft. is a better depth for posts in soft ground or ground that freezes deeply in winter. Increased depth of setting, requires, of course, a longer post. The post should be at least 6 ins. in diameter at the large end and that end should be set in the ground. For either board or wire fence the posts should stand an equal hight above the general surface of the ground and they should extend but little above the top board or wire. To obtain such uniformity it may be necessary in cases to vary slightly the depth of setting. If the lengths of the posts vary—which they should not—the tops of the long posts may be sawed off, if the digging is too difficult for setting the post an extra depth, but posts considerably shorter than standard length should not be used.

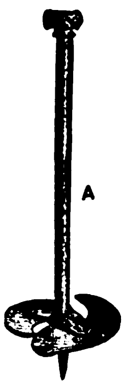


Fig. 420.

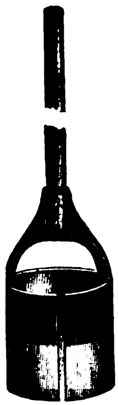


Fig. 421.

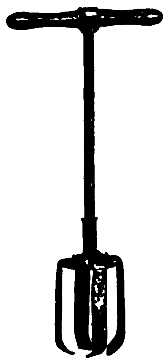


Fig. 422.

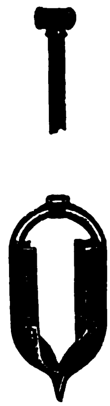


Fig. 423.

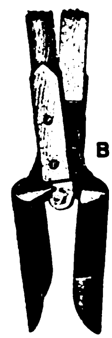


Fig. 424.

Post-Hole Augers and Diggers.

The right of way boundary is usually located by measuring out from the center of the track. On tangent such measurements need not be taken at nearer intervals than 100 or 200 ft., as the posts between can be lined by the eye, or perhaps better by stretching a chain tagged at intervals corresponding to the spacing of the posts. Along curved track the distance to the boundary should be checked at least every 50 ft. Post-hole excavators or "diggers" are much used in setting fence posts, and in mellow ground or where there are but few stones they are labor-saving devices, doing the work more rapidly than a bar and shovel or "spoon" (Engraving *E*, Fig. 419). An ordinary post-hole auger is shown as Fig. 420. Figure 424 shows the lower portion of the Eureka post-hole digger, commonly known as the "scissors" type. It consists of a pair of pointed segmental spades so jointed together that when rotated they cut a cylindrical hole, and by spreading the two handles apart they close upon the material, tongs-fashion, so that it may be lifted out of the hole. In hard ground the material must first be loosened by jabbing with a bar. Figure 421 shows the Champion digger with an iron handle. Figure 423 shows the Rapid post-hole auger and Fig. 422 the Monarch post-hole auger. The blades of the latter are radially adjustable to bore holes 7 to 9 ins. in diameter. In favorable material the blades are usually filled in four revolutions. This auger has been used in digging wells as deep as 30 ft. These excavators will take out about a gallon of dirt at each lift and they dig a hole but little larger than the post.

Three men can work together to advantage in setting posts, one man digging the holes and two men setting the posts and tamping the dirt around them. The man who digs the holes cannot keep out of the way of the post setters, and so whenever they overtake him he goes ahead and starts a new hole, while one of the post setters completes the unfinished hole and the other man carries posts over from the track. Under very favorable conditions three men have dug the holes and carried and set 180 fence posts in a day, but an ordinary record would be about 100 posts per day.

In boggy land where fence posts will not hold, and on rocky ground where post holes cannot be excavated by ordinary methods, the posts may be mortised or drift-bolted to sills of old ties or old bridge timber laid down transversely to the line of the fence. To secure the post in the upright position a brace piece may be spiked to the side of the sill and the side of the post. On rocky ground A-frames are sometimes substituted for posts, such being made by using two posts for the legs and tying them across the bottom by spiking a piece of fence board on each side.

Posts for a board fence are usually set 8 ft. apart center to center, and the boards in most common use are 1x6 ins. x 16 or 24 ft. long, of culled pine, hemlock or other cheap lumber. A fence four boards high will answer, but it is better to have five boards, especially if there are small animals, like pigs and lambs, to keep out. In a four-board fence the bottom of the first board should be about 4 ins. from the ground, then a 6-in. spacing between it and the second board, the two other boards dividing equally the remaining space. All of the boards should be nailed to the field side of the posts and be cut to meet those of another panel end to end, instead of overlapping. It strengthens the fence very much if the boards are made to break joints at the posts, but on uneven ground this plan is not practicable; otherwise, that is, if the ends of all the boards meet at the same post, a 1x6-in. batten as high as the fence should be nailed over the ends of the boards to cover the joints. It also strengthens a fence to use a cap board. This board is sometimes nailed flat on the tops of the posts, but it is considered better practice to cut the tops of the posts off to an angle of 25 to 45 deg. with the horizontal, and it is preferable to have the cap meet and cover the edge of the top side board. Each board should be nailed to each post with three 10d wire nails at the ends and with two at the middle post. A fence built of 16-ft. boards without battens will require 45 lbs. of nails per mile per one board high. There are 65 10d wire nails in a pound. A good way to arrange the work of nailing on boards is to have two men go ahead and tack them to the posts, with one man to follow after and complete the nailing.

Ordinary barbed wire, commonly known as "cattle wire," consists of two twisted strands with a two-pointed barb about every 3 ins. The weight of a single wire per mile is 330 to 380 lbs. "Hog wire" has four-pointed barbs and weighs about 400 lbs. per mile of single wire. Buckthorn barbed wire is a steel band or ribbon with ¼-in. saw-teeth barbs about 1-in. apart on the edges of the band. In order to present barbs in all directions the wire is twisted. This wire is more easily seen by stock than strand wire. Both twisted ribbon and twisted strands without barbs are used to some extent for fence wire. Barbed wires stretched over long panels are sometimes tied together by pieces of band iron at intervals of about 8 ft. between the posts, to prevent the wires from sagging or being spread apart. Staples, of the size commonly used in building wire fence, number about 70 to the pound, so that about 5 lbs. are required per wire per mile, posts 16 ft. apart.

Wire fence should be at least four wires high, or three wires with a board or stretcher at the top; but six wires alone or five wires with a top board are considered only ordinary construction; it requires six or seven wires to keep hogs, sheep and calves from crawling through. To hold such animals there should be four or five wires within 2 ft. of the ground, the lower wire not farther than 3 ins. from the ground and the next two spaced at 4 ins. In some states the law allows posts for railway wire fence to be placed as far as 30 ft. apart, if pickets are interwoven between and the wires stapled to the same, to make them act together and maintain them at an even spacing. Thirty feet, however, is too far apart. Where a board or rail is placed at the top the posts should not be farther than 12 ft. apart and the boards should extend over two panels. For an all-wire fence the posts should be not farther than 16 ft. apart, or 20 ft. where there are pickets or stays fastened to the wires between the posts. On some roads the posts are set as close as 8 ft. apart.

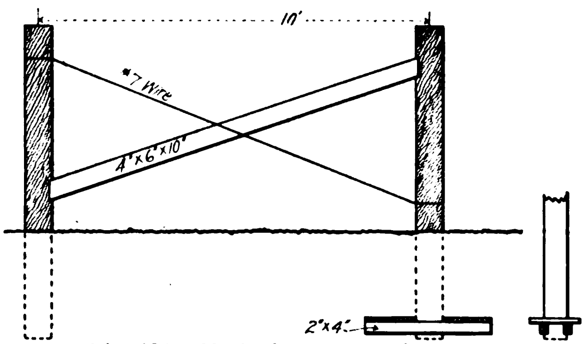


Fig. 425.—Methods of Anchoring End Posts.

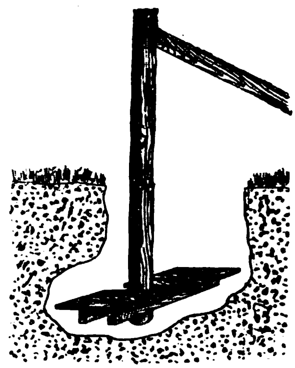


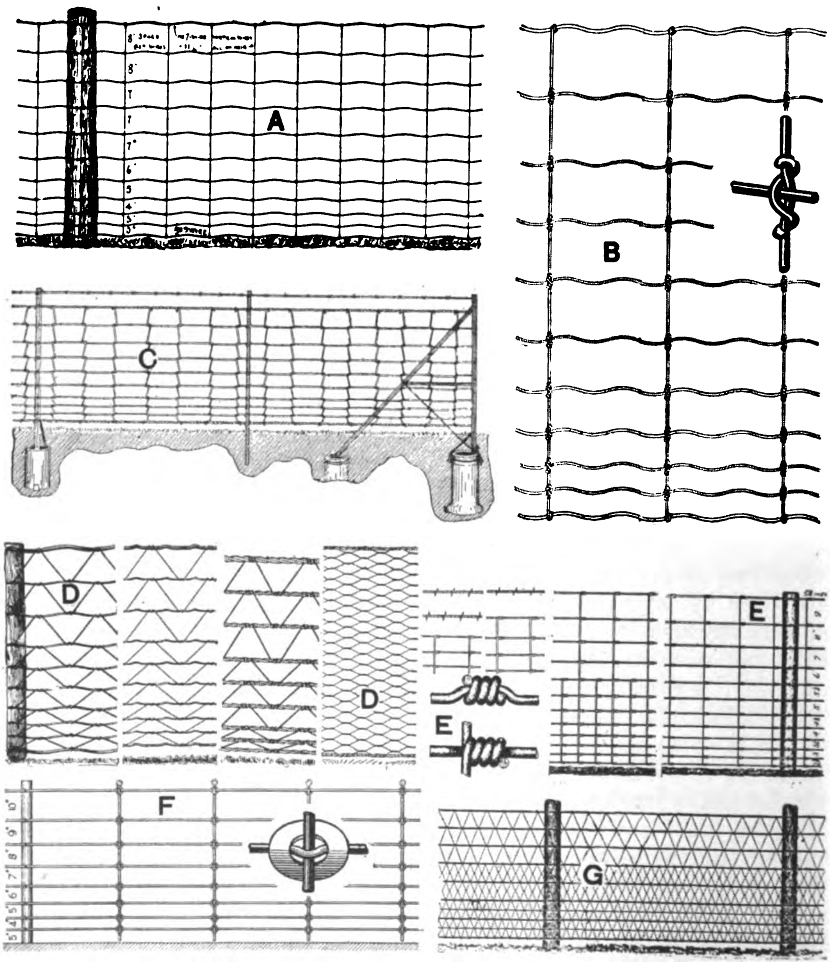
Fig. 426.

Posts at the end of a wire fence or at each side of a gate or cattle guard should be braced by a leaning post, the foot of the latter being supported against the adjoining fence post at the ground, or against a stake firmly driven; and posts at intervals of 200 ft. should be braced, either with two leaning posts or by heavy stay wires wrapped around the top of the post and anchored to adjoining posts at the ground. Figure 427A shows another method of bracing end posts. End and corner posts should be larger in diameter and longer than the intermediate ones, and should be set 4 to $4\frac{1}{2}$ ft. in the ground. Additional bracing may be given to an end post by nailing an anchor board across the post near the bottom, on the rear side, and another near the top of the hole on the front side, with reference to the direction in which the wires pull. Corner posts should be braced with leaning posts butting at the ground against other fence posts (Fig. 425) placed at half panel distance from the corner. A braced post or a post which comes in a hollow should be anchored, to resist being pulled up by the tension of the wires. One way of doing this is to bore a hole through the post near the bottom and run a bar of iron through the hole; another way is to spike a piece of board across the post near the bottom, and preferably on each side of the post. A very secure method of anchoring a post is shown in Fig. 426.

The bottom wire may be anchored between the posts by driving a stake into the ground and securing the wire to the stake with a staple, or a stone with a tie wire attached may be buried 18 ins. or 2 feet deep to serve as an anchor. The necessity for anchoring the bottom wire arises where the posts are a long distance apart or where the wire crosses a low spot in the ground.

If the fence is a combination board and wire structure the boards should be nailed to the posts before the wires are stretched. On uneven ground only one wire should be reeled out and stretched at a time. Where two or more wires are unrolled before any is stretched they get tangled. Some prefer to follow this plan in all cases, but where the ground is even over long distances it is commonly the practice to first reel out all the wires ready for stretching, the wires lying on the ground some distance apart or at different distances from the fence line, to prevent tangling. Then men are stationed 15 or 20 rods apart, and one man does the stretching with block and tackle while the others pick the wire up out of the grass and hold it off the ground until it is tight enough, when each staples it to the post where he is standing. This procedure is repeated with each wire until they are all up and stapled to enough posts to prevent appreciable sag, when each man proceeds to drive all the remaining staples on his section. The posts should be marked to indicate the spacing of the wires, and for this purpose use may be made of a marker board or gage. It takes a man 1 to 1¼ hours to mark the posts for a mile of fence. To reel out the wire a bar is run through the roll and two men carry it between them, but where there is a top board they put the bundle of wire up and roll it along on the fence, steadying it with the bar. On level ground one man can do this alone, but up and down hill two men are required. In stretching the wire it is pulled taut over a number of panels and tacked to several posts near the stretcher before letting go. It is a good plan to have the stretcher right along with or just behind the roll of wire and to stretch it up and secure it to the posts as fast as it is reeled out. It is a good deal of bother to pull up the slack when the reel gets far ahead of the stretching. The wires should be put on the field side of the posts, except on fence which bounds the inside of a curved right of way, when it should be on the track side; although in cases of this kind the wire is sometimes stapled to alternate sides of consecutive posts. On corner posts the wire must, of course, be placed so as to pull against the post. A serviceable and convenient form of wire stretcher is a handspike with a small claw plate screwed fast at one end, for catching the wire behind a barb. The wire is stretched by taking a pry back of a post, and to prevent the handspike from turning when straining on the wire the end holding the claw should be about 4 ins. wide and flattened. In the absence of a stretcher a hold may be had on the wire by giving it a turn once or twice around a handspike or bar. Block and tackle is also used much for a stretcher. Fence wire stretched in cold weather should be drawn up pretty tight, else it will sag in summer; if stretched in warm weather it should be drawn taut but not put under heavy tension, lest it will break when it contracts in winter. In putting up the wires four men can work to advantage: two to roll out or string out the wire, one to use the stretcher and one to tack the wires to just enough of the posts to secure them temporarily. Later one man goes along and nails them solidly to all the posts, driving all the remaining staples.

Labor Data.—The cost of labor in fence construction is quite variable in different localities, even with the same type of fence. The topography of the right of way, and its condition respecting growth of trees or brush; the condition of the ground as affecting the digging of post holes, the experience of the workmen, and sometimes other matters, have a considerable bearing upon the result of each day's labor. The same amount of effort might accomplish much more or a good deal less in one place than in another. Labor data on fence building should therefore be regarded conditionally. With this understanding the following statement, except where otherwise expressed, refers to ordinary work under ordinary conditions. A working day is supposed to be 10 hours. Where an auger or digger can be used effectively a man will dig 100 to 125 post holes 2½ ft. deep, in a day; or 50 with bar and shovel, where there are but few stones. In one day a man will carry and set about 70 posts. A day's labor will carry about 600 16-ft. boards from the side of the track to the fence line on a 100-ft. right of way. If the ground is hilly or rocky or if there are brush or logs in the way it may not carry more than half as many. A day's labor will cut to length and nail on about 90 fence boards, with battens, each board being nailed to three posts. In building wire fence with a top board a day's labor will carry from track to fence line about 450 boards, and it will cut to length and nail on about 160 boards, each board being nailed to



A, Page Fence; B, Lamb Fence; C, Mathews Fence; D, McMullen Fence; E, American Fence; F, Jones Fence; G, Ellwood Fence.

Fig. 427.—Woven Wire Fence.

three posts. A day's labor will reel out, stretch up and nail to posts 12 to 16 ft. apart about 6400 ft. of barbed wire (single wire).

Assuming that one man will dig the holes and carry and set 35 posts in a day, which would be an average record, the time required to build one mile of fence of various kinds is roughly estimated below. No allowance is made for delays in clearing brush or in building around stumps or other obstacles. The work of building a four-board fence, 16-ft. boards, posts 8 ft. apart, without battens, requires about 29½ days' labor; with battens, 36 days; a five-board fence, or a four-board fence with cap board, with battens, 41 days. The labor of building a barbed wire fence four strands high, posts 16 ft. apart, is about 13 days' work; with posts 12 ft. apart, 16 days; with top board and three wires, posts 12 ft. apart, 17 days; with top board and four wires, posts 12 ft. apart, 18 days. For a fence with a different number of wires allow about 8 hours' labor for each wire, more or less as the case may be. Experienced fence men working by contract will build just about 50 per cent more fence in a given time than the same number of ordinary track laborers engaged in the work only a short time each season. Thus, on a certain railroad the average record for the section men was 17½ days' labor per mile of fence built, with top board and three wires, posts 12 ft. apart. The average record for a gang of experienced fence men, working for the same company at the same time, under similar conditions, the same number of hours per day, but for a contract price per rod, was 12 days' labor per mile of fence.

Woven Wire Fence.—The necessity for keeping small animals off the right of way has led to the extensive use of woven wire fence along railroads. The method of construction in most forms of woven wire fence consists in tying together a number of horizontal wires with cross wires, to form a fabric or mesh of some desired shape. The cross wires serve to keep the horizontal wires at proper spacing, and thus woven wire is supposed to permit the use of fewer posts than are required for a fence built with independent wires, but in practice such hardly proves to be the case. The woven fabric does, however, permit the use of lighter horizontal wires for the intermediates than would be serviceable were they stretched up independently; and by using lighter wire a larger number can be afforded, and hence a tighter fence secured. The cross ties in a woven fence add no particular tensile strength to the horizontal wires, but they do serve to prevent the horizontal wires from sagging when part of the same are forced out of the straining line and stretched. Figure 427 is composed of a number of engravings illustrating some of the forms of factory-made woven wire fence in railroad service. Engraving *A* is the Page fence, of "coiled spring" laterals and straight verticals, forming a rectangular mesh. The horizontal wires are of hard steel and the verticals are annealed. The top lateral in the example shown is of No. 7 wire, the bottom lateral No. 9 wire and the nine intermediate laterals of No. 11 wire; the vertical wires are No. 14 and the spacing of the laterals is indicated on the engraving; the vertical wires are spaced about 12 ins. apart. The spiral twist in the lateral wires is produced by coiling the wire around a ¾-in rod and then pulling it out again. The purpose of this twist is to put the fence in tension upon being stretched up and fastened to place, so that it will automatically adjust itself for expansion and contraction due to change of temperature, and enable it to return to its original shape after being run against and stretched by stampeded cattle or other animals. The Lamb fence is similar to the Page fence and is shown as Engraving *B*, the knot or method of attaching the verticals to the laterals being also shown.

Engraving *C* shows the Mathews woven wire fence stretched upon steel posts already described. The top and bottom selvages are straight and the intermediate laterals are bent or depressed at intervals of 12 ins., and into these bends are wrapped the vertical stays, the idea being to keep the latter from slipping out of place. The top and bottom cables are formed of two No. 11 hard steel wires twisted together; the other laterals are of No. 11 hard steel spring wire; and for the vertical stays No. 12 annealed steel wire is used. The vertical stays are wrapped four times around the top and bottom cables. The fence as shown is constructed with barbed wire for the top strand. The steel and sewer-pipe posts are placed two rods apart and a stay rod is driven half way between the posts to act as a stiffener. The wire netting is fastened to the post by cutting a small slot in the post, dropping the strand of wire into it and then closing the slot with a hammer. The Keystone woven wire fence has a mesh similar to that of the Mathews.

Engraving *D* shows four patterns of McMullen woven wire fence, the first section on the left being of the "spiral spring steel" type, in which the horizontal wires are spirally curved to provide for expansion, contraction, etc. The top wire is of No. 7 gage, the intermediates of No. 11 and the bottom wire of No. 9 gage. The cross or tie wires are of No. 12 gage, spaced 24 to the rod. The next section is of the "crimped steel wire" type. The horizontal wires have a special crimp for preserving a "springy quality." The tie or cross wires are of No. 14 gage, with 24 meshes to the rod, the fabric being otherwise made up as in the case of the spiral spring type. The next section to the right is of the "steel wire cable" type. The top cable is of four strands of No. 13 steel wire and the other laterals each of two strands of No. 13 steel wire; with No. 13 cross or tie wires, 24 meshes to the rod. The form shown as the right-hand section of the engraving has a diamond mesh, intended especially for holding hogs and other small animals. The mesh is made in two sizes—2x4 ins. and 3x6 ins. The selvages are of twisted wires of No. 14 or No. 15 gage and the netting strands of No. 15 or No. 16 wire. The netting is made in various widths to suit different purposes.

Engraving *E* shows the 12-bar American woven wire fence in four different styles. The top and bottom wires are No. 9, the intermediate laterals No. 11 and the stay wires No. 12, spaced about 12 ins. apart. For holding the smaller animals the fence is made with an extra stay running in between the regular stays for a few meshes up from the bottom, as shown in the second section from the right. For a cattle fence one or two strands of barbed wire are stretched above the netting, as shown in the two left-hand sections. The Clinton woven wire fence has straight wires with rectangular mesh, the verticals and laterals being electrically welded together. Engraving *G* is an illustration of the Ellwood fence, formed upon twisted lateral strands, with a triangular mesh formed by stays running diagonally. The meshes near the bottom of the fence are smaller than those at the top, so as to take care of the smaller animals. "Hog fence" is a special form of woven wire fence made by nearly all of the woven wire fence manufacturers, in which the bottom portion of the netting for a hight of from 24 to 33 ins. above the ground is formed by closely spaced horizontal wires with numerous stays, so as to secure a small mesh.

Engraving *F* in an illustration of the Jones "locked" fence. The laterals are straight wires spaced as indicated in the engraving, and at intervals these wires are locked to vertical stays by looping the wire through a ring and slipping the stay through the loops of all the laterals. The standard fence of this type has No. 9 lateral wires throughout, with No. 7

hard steel wires for the stays, which are spaced 2 to 3 ft. apart, according to the panel length. These stays are applicable to old as well as to new fences and to either barbed or plain, straight or spiral-spring wire. The stay is applied to wires already attached to the posts by crimping the wires with a special tool, working from top to bottom, and in order to slip the stay through all the wires easily the rings or clamps are first doubled over and after the stay is in position they are spread to lock the wires firmly to the stay.

To prevent old barbed wire from swagging it is quite customary to use stays between the posts. Wooden pickets or slats interlaced with the wires, using staples to secure the latter and preserve the proper spacing, are frequently employed. Besides the Jones stay and method of locking there is another device for a similar purpose known as the Crescent stay. It is long enough to engage two or more wires, as may be desired, and consists of a piece of steel of trough section, $^3/_{64}$ in. thick and about 1½ ins. wide, notched on the edges to engage with the wire. The fence wire is secured to the stay by tying with a wire loop, which is drawn very tight by means of a special tool.

Woven wire fence comes from the manufacturer in rolls of 20, 30 or 40 rods' length, and sometimes in rolls as small as 10 rods, if so ordered. A whole roll is usually stretched at one time. The netting is unrolled flat on the ground, the bottom of the fence next the posts. The end of the fence is then made fast to the starting post, wrapping the strands clear around the post and fastening well with staples both at the extreme end and on the back of the post. The stretcher is then put on at the other end of the roll and the fence pulled up tight to place. The netting is stretched up either by pulling on one wire at a time (the top and bottom wires first) or by clamping the netting between two tongued and grooved pieces bolted together or to a stretcher bar provided with a special clamp for each horizontal wire, and then pulling on the clamping device with block and tackle, ratchet and chain, or other mechanical contrivance. In splicing sections of woven wire together the individual wires of the netting are spliced together, the joint made being similar to or like that made in splicing telegraph wire. In building woven wire fence across a hollow the wire netting is usually stapled to the last post on one side of the hollow and then stretched up at a post on the other side. The netting is brought down to the posts in the hollow by stepping on the bottom selvage and pulling it down to place, slacking off on the stretcher as the fence is depressed from post to post, but keeping a good tension all the while. In stretching over a hill the fence is pulled partly up and then hung up on the highest post on a staple loosely driven. After that it is stretched tightly to place. In stretching woven wire netting up to an end post it is usually necessary to set a straining post behind the end post, temporarily, in case there is nothing else in line with the fence to which the stretching apparatus can be attached. Posts for woven wire fence are usually set 12 to 16 ft. apart, but sometimes as close as 8 ft. apart. The cost of building woven wire fence, posts 12 ft. apart, is in the neighborhood of 20 cents per rod. The average cost for labor in erecting 22 miles of Page woven wire fence, as shown by the reports of the fence gang of a certain railroad, was 17.2 cents per rod. The posts were set an average distance of 17 ft. apart, and 3 to 3½ ft. in the ground. The surface was generally rough and uneven and a great many anchor posts had to be used. The cost stated covered the labor of loading and unloading new material, removing the old fence and disposal of the same, either by piling or burning, and the time consumed in moving the fence gang from one point to another.

Combination barbed and woven wire fences are used a good deal, especially where it is necessary to hold small animals. A committee report to the Roadmasters' and Maintenance of Way Association, in 1902, recommended for a hog-tight or sheep-tight fence in level country, a 26 or 28-in. netting of woven wire (square mesh) at the bottom, with three barbed wires on top. The standard wire fence of the Toledo, Peoria & Western Ry. consists of Keystone woven wire fencing 25 ins. high for the bottom, put on 2 ins. clear of the ground, with three four-point cattle wires spaced at 6 ins., 8 ins. and 10 ins. for the top. The posts are 7 ft. long, set 12 ft. apart and 2 ft. 7 ins. in the ground. Other details are shown in Fig. 427A. The left of the figure shows the braced panel that is standard with this company. The end post is extra heavy, and between this and another post set at a distance of 7½ ft. c. to c., there is a 7-ft. post used horizontally as a strut. The third post is 6½ ft. beyond the second, and is used as a footing for a 7-ft. brace post. The tops of the second and third posts are

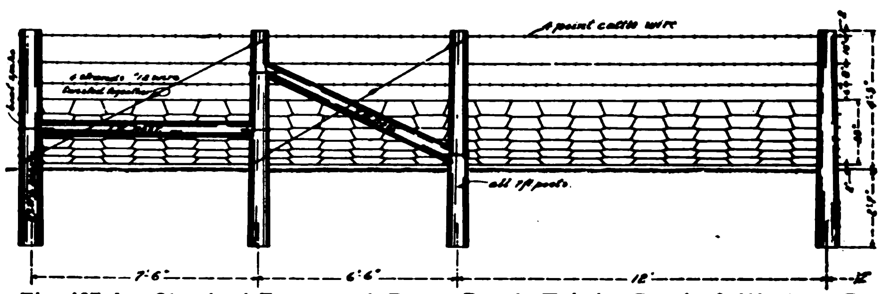


Fig. 427 A.—Standard Fence and Brace Panel, Toledo, Peoria & Western Ry.

then stayed to the end post by four strands of No. 12 wire twisted together. The posts and braces are firmly secured together by boat spikes.

Fence Machines.—Woven wire fence is also made in the field, with machines operated by hand power, and such machines have been used to some extent in railway work. The line wires, which may be either plain or barbed or part of each, are first stretched up alongside the posts, as in building strand wire fence, utilizing old fence wire already in place, if desired, and then the machine is worked along these wires to twist on or "weave in" the cross ties to form the fabric. There are several kinds of these machines, but on general lines the construction consists of an upright iron or wooden frame as high as the fence, on which are arranged a series of tubular spindles, spool carriers and twister wheels turned by a crank and gearing (Fig. 446A). The line wires pass through the spindles, and the spools which carry the cross wires are revolved around the spindles and automatically transferred, first to the upper and then to the lower spindle of each set of two, each time a new row of meshes is formed. Each distinct operation of the machine, as it is moved along, forms a series of meshes from top to bottom of the fence. The base of the machine, about 8x14 ins. in size, is carried upon small wheels which run upon a plank laid down on the ground. The machine builds fence over hilly and uneven ground without trouble. In making vertical turns to follow the lay of the ground the machine makes the meshes at top and bottom of different length, so that the fence fits the ground and does not require so much anchoring in such places as does factory-made fence. The meshes can be made very wide or close enough to turn small chickens, simply by varying the adjustment of the machine, and it can be used to weave numerous kinds of meshes, including ornamental designs. The machine is run by a man and a boy—the man to weave and the boy to fill the spools with wire for the bobbins. Such an outfit can weave 40 to 70 rods of fence in a day, the speed depending upon the size of the mesh. Mr. John Wirley, roadmaster with the Lake Shore & Michigan Southern Ry., has used one of these machines in building right of way fence. The labor cost one year was 33.7 cents per rod of fence, including the taking down of the old fence, setting new posts and weaving the new fence. During another year the average cost was 63.1 cents per rod of fence, including all material and labor. As used on this road a man and a boy have woven 60 to 70 rods of fence per day.

Durability.—Experience has shown that fence wire for railway service should be thickly and uniformly galvanized. Wire in right of way fence is exposed to sulphurous smoke and cinders from locomotives, and parts of the metal which are unprotected or too thinly coated are rapidly corroded. Trouble of this kind has occurred most frequently with woven wire fence, the smallest wires giving out first. In some instances the mesh wires have entirely rusted out in four to five years. Different authorities have laid the fault to inferior galvanizing, due to careless or too rapid work in the manufacturing processes; and to scaling or peeling of the spelter in the process of passing the wires through the weaving machines. The fact of failure under the influences stated has in some instances been made the basis of recommendation for the use of larger wires than are required in fence of ample strength to resist stock. As increase in size of wire increases the cost, and since the matter of failure as between a large and a small wire is only a question of time, wherever the corrosive action is present, the suggestion of larger wire is not altogether satisfactory. Failures of wire fence from corrosion have been most rapid where the quantity of locomotive or bituminous coal smoke has been greatest, but such failures have not been confined to the vicinity of roundhouses and switching yards alone; it has been found to prevail to more or less extent along the entire length of some roads, being most marked where the exposure is greatest, or in places where the smoke is driven to the ground. The inception and progress of the corrosion has been watched closely and found to appear first in spots, in some instances only one or two wires being affected for a considerable distance. This fact would seem to indicate that the galvanizing of the wire was not everywhere uniform.

Gates.—A gate of substantial construction can be easily made by uniting a panel of horizontal boards by vertical pieces or battens at the ends and at the middle, using clinched nails. Preferably there should be double battens—that is, a batten on each side of the panel—at each of the three points, and to hold the gate in shape a diagonal strip may be nailed to the panel, running from the top corner on the free end of the gate to the bottom of the middle batten. In hanging the gate the bottom edge of the top board may rest upon a pin or cross piece between staggered posts. The gate may then slide back half its length and be swung around at a balance on the cross piece. Another way to support such a gate is to hang it upon two track spikes driven into the post, hook upward, one spike coming under the top board and the other spike under the second board from the bottom, to keep the gate from swinging outward at the bottom. In constructing a swing gate the vertical end piece to which the hinges are attached should run up considerably higher than the panel of boards, and the diagonal or brace strip should be run from the top of this vertical piece to the bottom corner of the swinging end of the panel. Figure 428 shows a convenient form of gate which can be improvised with materials obtained on any railroad section. Old switch ties may be utilized for gate posts, and the swinging panel is made of 1x6-in. fence boards of 16 ft. or other available length. The hinge piece is set leaning, so that the gate will rise when opened and swing to the closed position when released. For a top hinge an old fish plate or angle bar spiked to the gate post will suffice, and a piece of old tie bedded in the ground with a dowel pin running into the hinge piece, serves as a bottom hinge. The gate may be held in the closed position by a stop piece and a wooden peg stuck into the gate post, or by some form of latch. To prevent cattle rubbing against a gate several strands of barbed wire may be stretched across it on the field side.

To admit farm machinery, gates should be at least 15 ft. long, and for several reasons swing gates should be arranged to open only on the field side, or away from the track. One of the most important of these reasons is that a gate which swings toward the field has the support of the post when cattle crowd against it from that side, while if it opens toward the track it is held by the fastenings, and if these are faulty or the timber to which they are attached somewhat decayed, the gate is liable to be thrown open from pressure in the manner stated. Another reason is that while a team is standing on the right of way waiting for the gate to be opened it may have to stand dangerously near the track if the gate swings that way; if the gate swings toward the field the team may be driven right up to it before it is opened, and not nearly so much damage is liable to occur should the team become frightened and run into the gate before it has been swung en-

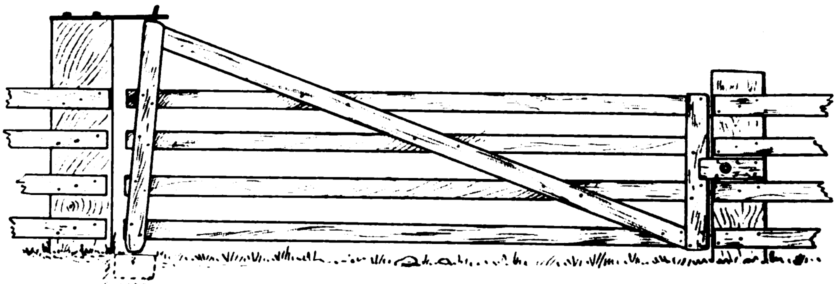


Fig. 428.—Gate for Railroad Fence.

tirely open. It is the duty of section foremen and track-walkers to see that gates opening into the company's right of way are kept closed when not in use.

Fence Crews.—In order to work to advantage in building a fence a gang of at least four men is needed. Where there is much fence to be built it is a better plan to set one or more fence crews at work than to take the section crews off the track to do it. It is customary to pay a contract price per rod or hundred feet of fence built, the company furnishing the material. The gang should be furnished with a box car to carry tools, supplies of wire, nails, staples, etc., and a hand car. Where supplies are not carried in this way it is often inconvenient to get them to the gang just when wanted. Posts and boards should be unloaded in advance of the work. In dropping boards from a car in motion, as in distributing fence material from a slowly-moving train, the trailing end of the board should be dropped first; otherwise there is danger of accident to the men on the car. The safest practice is to forbid dropping long material of any kind from a train in motion, but in unloading fence boards this rule is not always observed. The supply car should be set out at the side-track nearest to the work, and the gang may find it necessary to furnish their own board, as there will sometimes be no other opportunity of getting board within reasonable distance.

Some roads have cars specially fitted up for fence gangs. The fence men's car of the Toledo, Peoria & Western Ry. (Fig. 428A) is 45 ft. long and 8 ft. wide, inside, and has a platform on one end. In this end of the car there is a room 22½ ft. long fitted up for living and sleeping quarters. The side walls are covered with matched and dressed fencing put on horizontally, over which is a layer of building paper, and then 10-in. stock boards and battens up and down. The ceiling is covered with 10-in. stock boards and battens running lengthwise the car. The battens are laid on in fresh paint and nailed every few inches, so that there are no cracks. The flooring consists of matched and dressed fencing crosswise the car, overlaid with paper and then with hard pine flooring running lengthwise. One object in view in the inside finishing was to make the car as nearly vermin-proof as possible. The frames of the bunks are all made of 1-in. gas pipe. There are three sections of beds three berths high, besides a single bed, providing accommodations for 10 men. The beds have movable woven wire springs. There are also a desk fastened to the wall with angle irons and provided with a drawer underneath, a water tank and wash basin, a stove, and four lockers 18x20 ins. by 6 ft. clear hight. Passing from this room through a side door at the left, entrance is made to the hand-car or tool room, which is 9 ft. long, with doors 6 ft. wide on either side. In this room there is a work bench 2 ft. wide and 6 ft. long, with space underneath for coal, nails, fence staples, etc. Ten feet of space in the end of the car is used for a barbed wire bin, which is partitioned off by cross bars fitting in stirrups bolted to angle irons reaching from floor to ceiling. Light is admitted through windows and transoms, some of the windows being specially

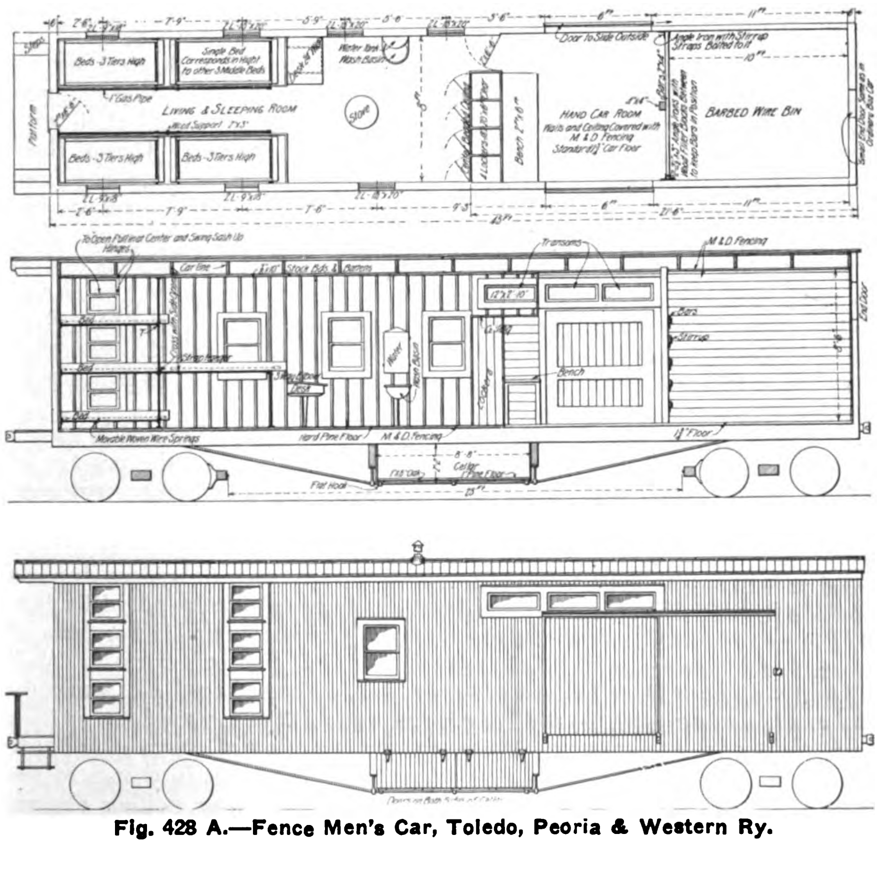


Fig. 428 A.—Fence Men's Car, Toledo, Peoria & Western Ry.

arranged to give ventilation to the sleeping sections, there being a window to every berth. Under the car there is a cellar of good size, with two doors on each side. The fence gang, consisting of five to nine men and a foreman, according to the condition of the fences, is engaged each year from about April 1 until the ground freezes up in the fall, or about eight months.

Fence repairing, like a great many other things on the railroad, usually requires immediate attention, and much of it must be looked after by the section crews. There is some work which can usually be done on fences during winter, when other work is scarce. Wherever the posts are in good condition weak places may be strengthened by nailing on new boards where old ones have been split, or loose wires may be tightened, corner and end posts braced etc., but wherever the work of repairing involves resetting or straightening up of the posts, nothing more than urgent work should be done until after the frost leaves the ground. Staples and 10d. wire nails should habitually be carried on the hand car, so that light or temporary repairs can be attended to when the need is first seen; otherwise such matters are liable to be neglected.

Use of Fence Wires for Telephone Lines.—In sections of the country, particularly in the West and Southwest, where there are long stretches of right of way wire fence with but few or no breaks of consequence, considerable use is made of the wires for telephone circuits, both by private parties and by the railway companies. As the posts insulate the wires from the ground it is only necessary to keep the strands that are used from contact with the other wires and to jump the road crossings, culverts and cattle passes, which can be done by erecting poles and carrying the wire over at a hight sufficient to clear hay wagons or whatever may pass. If a complete metallic circuit is desired the top wire of the fence on both sides of the track is used. In dry weather these wires can be used with good service up to a distance of 100 miles. In Texas the Southern Pacific Co. has a number of wire-fence telephone lines in service, affording communication with section houses situated at a distance from telegraph stations. One of these lines extends from Sierra Blanca to Dalberg, 28 miles, and another from Marfa to Valentine, a distance of 35 miles. In the latter case there are two section houses at "blind sidings" that are served by the telephone line. There is no expense for installation except for a telephone instrument at each point of communication, and a trifle for wire to bridge over gates and other gaps in the fence. In the arid region the working of the system is entirely satisfactory. The telegraph stations being widely separated, this cheap means of communication with isolated section houses in times of emergency is greatly appreciated.

152. Cattle Guards.—A stock guard, commonly called cattle guard, is a barrier of some kind in the track intended to prevent the passage of stock. It is used principally at either side of grade highway crossings, where the track is fenced in, being in principle a means for preserving a continuity in the fence past the track; it is frequently used also at private road crossings with the track and to guard the approach to bridges, tunnels and deep cuts. Like right-of-way fence, cattle guards are required by law, but in no case does the law of any state specify a particular kind or form of guard. Such terms as "sufficient cattle guards," "proper cattle guards," "suitable and sufficient to prevent horses, cattle, sheep, hogs," etc., are common expressions embodied in the language of different state laws on this point. On some roads the building and maintaining of cattle guards are put in charge of the track department and on other roads in charge of the bridge and buildings department, but as a general thing neither department craves the job.

In general, cattle guards may be divided into two types: pit and surface guards; and of the former type there are two kinds—open and covered pits. Practically, there is only one barrier which can certainly prevent domestic animals from traveling the track, and that is an open pit so wide that they cannot jump across it and so deep they cannot jump out in case they get into it. A frightened animal running before a train will not always turn aside, even for a deep pit. A common form of pit guard is an excavation 8 or 10 ft. long (measured with the track), 10 ft. wide and 3 to 6 ft. deep under the track, walled up with framed timbers or masonry. If the excavation serves also for a waterway or open culvert, as is frequently the case, the side walls are omitted; but in any case means should be provided for draining the pit. In the West, where pile structures are common, each wall is usually composed of three piles with a 12x12-in. cap, backed by a bulkhead to retain the roadbed. At an open pit the rails are supported upon stringers direct—usually wooden stringers with the upper corners chamfered away nearly to the base of the rail. The chamfering is necessary in order to prevent animals—particularly hogs and sheep—from walking the stringer astride the rail. It is safe to say that the open pit properly constructed will stop stock. There are, of course, those who will declare they have seen some old cow do the tight-rope act and walk the rail over the pit, but such exhibitions may properly be considered unusual and of infrequent occurrence; and no doubt room could be found for all such rare animals in menageries, where they could make their living easier than by picking it along the track.

Pit Cattle Guards.—While the open pit answers admirably the purpose of a cattle guard it is nevertheless objectionable from almost any other standpoint of the railway company and the public as well. It forms an opening into which a derailed truck will drop and cause a wreck. The stringers constitute a bridge of short span, and if these or any other of the parts are of timber the structure must necessarily be watched against fire as closely as any wooden bridge. The open pit is a constant menace to the lives of people traveling the track after dark. It is necessary, of course, that trainmen, watchmen, and other employees should use the track at all hours; but from the fact that American railroad tracks are, for foot passengers, equivalent to public highways, the majority of people who have been injured by falling into pit cattle guards have been of the common public. Pit guards are objectionable in many ways, also, when looked at from the standpoint of track maintenance. Any break in the continuity of the roadbed, such as at the ends of bridges and at open culverts, always increases the work of maintaining a good surface at that point. It is desirable, therefore, to have as few of these breaks as possible. Low joints are more liable to be neglected at or near planked road crossings than anywhere else; and to place a pit at each side and near the crossing only serves to increase the natural tendency to postpone repairs to the track surface at such points. Where the pit cannot very well be drained, as in a through cut, it will hold the water caught in wet weather, which will soak away into the roadbed and cause the track to settle. The exposure of the roadbed at the opening leads to deep freezing in winter, resulting perhaps in badly heaved track at the pit, which, in connection with a chance low joint at the crossing, puts a considerable stretch of track in bad surface. An open pit on a curve is a bad arrangement, because it leaves a stretch of track of some length without a tie to hold the outer rail against spreading. The best provision against such trouble is to box the stringers into a good-sized timber at their ends, or to hold them together with long bolts, but even then there is still the liability that the rail will spread by crowding the spikes and splitting the stringer.

The danger of spreading could easily be taken care of by notching the stringers at the middle and connecting the rails with a switch rod, but such a rod would be in about the right position to break a person's neck if he should walk into the pit, and it might also serve to catch and hold animals where they would form a dangerous obstruction to trains. Thus it seems almost criminal to place open pits in the track, and their use ought to be illegal. The very fact that the use of such pits (being the best barriers against stock) has not been enforced by law goes to show that they are in disfavor with the public. Moreover, railroad companies have for years been spending large sums of money on guard-rail appliances and ballasted bridge floors, to minimize the chances of serious wreck from derailed wheels; so that, in the light of modern improvements, the open pit cattle guard is out of date, and is fast going into disuse. It should be said, however, that if a pit is to be used at all it ought to be so deep that animals falling into it shall be clear of trains; and there should be placed over it nothing to catch and hold animals. A shallow pit is more objectionable than a deep one, because, while it is about as dangerous for a derailed truck to strike, the likelihood of an animal's making an attempt to cross it is greater than it is with a deep pit. A telltale placed each side of the pit, in the track, might serve as a warning to trainmen or trackmen running along the track after dark, whether or not it would to others. Such a telltale might consist of a few strips of lumber placed diagonally across the track, nailed to the ties—something like a surface cattle guard, say.

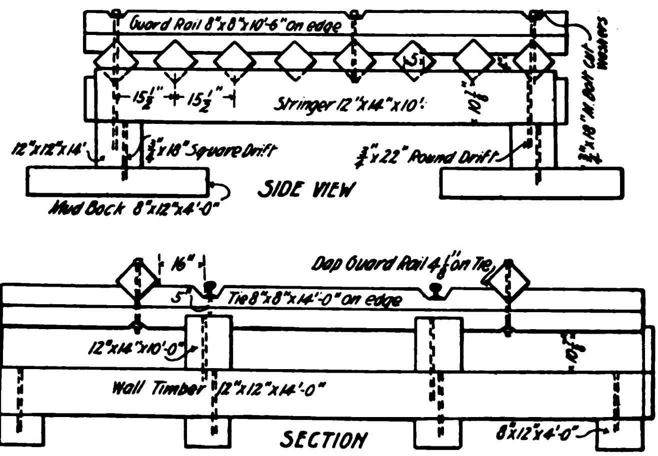


Fig. 428 B—Covered Pit Cattle Guard, Florida East Coast Ry.

The danger to train operation attending the use of open pit cattle guards is in one respect obviated, perhaps, by covering the pit with ties laid across the stringers to form a bridge floor. A timber guard is laid along the ends of the ties, on either side, and bolted to them, to prevent their being bunched when struck by derailed wheels and, except for the rail seats, the upper corners of each tie are chamfered off nearly to the center of the face, so as to present an insecure footing to animals. The pit in this case is usually shallower than the ordinary open pit. Such an arrangement, however, is hardly any improvement on the open pit guard, for if it does not actually destroy the effectiveness of the pit as a cattle guard it introduces a new element of danger to trains. If the pit is so shallow that cattle or other stock can touch the bottom they will step down between the ties and walk across, and if the bottom is beyond their reach they are quite liable to slip and be caught astride the ties when attempting to cross, thus being rendered entirely helpless. Instead of a cattle guard the contrivance then becomes a cattle trap, and if the unfortunate animal is struck in this position the train will almost surely be thrown from the track. There is also some question as to the ability of chamfered ties to carry derailed wheels safely, unless the ties be so closely spaced that they lose some of their effectiveness as a guard. All things considered, then, about the safest pit for train operation is the deep open pit. Hence, for the reasons above stated, the use of a pit cattle guard in any form should be discouraged.

Figure 428B shows a design of covered pit cattle guard that is standard with the Florida East Coast Ry. The ties are 8x8 ins. laid on corner. The guard is intended to be strong enough to carry derailed trucks and is said to be efficient in turning stock. In that part of the country there is no trouble from heaving of the track by frost, so that one of the objectionable features found with such guards in the North is absent. Following is the bill of material: 8 mud blocks, 8x12 ins. x4ft.; 2 wall timbers, 12x12 ins. x14 ft.; 4 wall planks, 3x12 ins. x 10½ ft.; 2 stringers, 12x14 ins. x10 ft.; 2 ballast boards, 3x14 ins. x14 ft.; 8 ties, 8x8 ins. x14 ft.; 2 guard rails, 8x8 ins. x10½ ft.; 4 round drift bolts, ¾ in. x22 ins. (for stringers); 8 square drift bolts, ¾ in. x18 ins. (wall timbers); 6 bolts, ¾ in. x18 ins. (guard rails); 12 cut washers for ¾-in. bolt. The timbers used, including the ties, scale 1805 ft. B. M.

Surface Cattle Guards.—Surface cattle guards are of two kinds, viz.: those intended to present to animals insecurity of footing and another kind intended to inflict pain. A surface guard properly built will turn away horses and ordinary cattle, but of cattle in the habit of roaming through woods there are some that will not stop for a surface guard if there is better grass on the other side. The kind of guard first mentioned usually consists of strips or slats of wood or metal spiked to the ties, either lengthwise or crosswise the track, both inside and outside the rails, and presenting upturned corners or edges. The ballast is usually removed as far as the bottoms of the ties, so that, to stall-fed animals or stock habitually pastured in cleared fields, it has an unfamiliar appearance which is supposed to put them in fear of attempting to cross. These strips or slats should be spaced at such a distance apart that there will either not be room for the hoofs of cattle or horses to slip between them, or else at such distance that when slipping between them there is room for their extrication. The form of surface guard designed to inflict pain is usually made of iron or steel slats, the upper edges of which are serrated or formed into saw teeth, or studded with spike-like projections. In either kind of guard the slats are sometimes spiked directly to the ties and sometimes they are held in end pieces running crosswise the slats and secured to the ties by spiking. As a usual thing the slats run parallel with the rails. A guard formed of slats running crosswise the track is known as the "gridiron" pattern.

As to the relative merits of the various forms of surface guards there is probably but little difference. Guards with wooden slats are the ones most generally used, and are perhaps as efficient as any. They are cheaper in first cost than metal guards and are more cheaply and easily repaired when torn out or damaged by dragging parts of cars or by derailed wheels; on the other hand there is with the wooden guard the disadvantage that it is occasionally subject to destruction by fire. As between the guard which renders footing insecure and that which inflicts pain it would seem that the latter ought to be the more formidable, since it necessarily partakes somewhat of the nature of the other also. The objection is raised, however, that so far as the pain is concerned, such a device is just about as severe on men who may chance to stumble upon it at night as it is upon

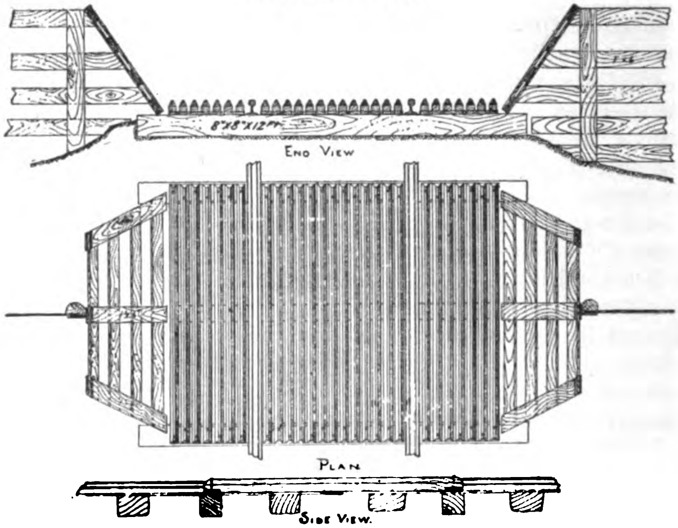


Fig. 429.—Standard Wooden Cattle Guard, Wabash R. R.

beasts; and if a flagman was to fall and strike his knee or elbow upon one of the prongs he would undoubtedly be in poor shape to signal a train.

From the foregoing considerations one might correctly infer that there is in reality no form of cattle guard that gives entire satisfaction. The two essential conditions of a perfect cattle guard—a structure which will safely carry the wheels of a derailed truck and which will form an impassable barrier to stock without entrapping the animals to the peril of trains—are incompatible with each other. The status of the cattle-guard problem is similar to that of the rail joint splice—the seemingly best solution (a welded joint) is either inexpedient or impracticable of application. Under the circumstances, the best practice seems to favor the use of the surface guard, taking advantage of any design or plan conducing to general effectiveness. A common fault with surface guards is that they are not made long enough. Horses will clear an 8-ft. guard at a single jump, and by stepping as far as possible with their front feet cattle will leap the rest of the way over a guard 10 ft. long. If cattle guards were made 15 or 20 ft. long, measured with the track, and well flanked by side fence, there would be but very few animals better domesticated than the Texas steer or the southern "razorback" hog that would attempt to clamber over them. On the Chesapeake & Ohio Ry. it has been found that 12-ft. cattle guards are much more effective than guards 8 ft. long. The Nashville, Chattanooga & St. Louis Ry. has at some places used two 8-ft. guards end to end, making one guard 16 ft. long. A point not to be overlooked in locating a cattle guard is to select a place where there is opportunity for stock to readily turn aside when confronted by the guard.

From all accounts obtainable it adds much to the effectiveness of a surface guard to give it a coat of whitewash occasionally. Many say that a whitewashed wooden slat guard has been known to stop stock where without the white color the stock would pay no heed to it. Others claim that black paint is even better than white. Either color is undoubtedly better than the natural color of the wood, as it gives to the structure the appearance of a distinct object in the track and adds a sort of scarecrow feature which ought to make the general appearance of things so much the more forbidding. An advantage with the white color is that it is conspicuous at night. Some who have tried both colors claim that the most effective scarecrow is to be had by painting the slats alternately white and black.

It may be of service to describe briefly some of the various forms of surface cattle guards in use. Wooden slat guards for single track are sometimes formed by spiking slats to the ties direct, but more usually they are grouped in sections—two sections to cover the space between the rails and a section about 2½ ft. wide to lie outside each rail. On some roads where wing snow plows are used the cattle guards are made wide enough outside the track to permit the side panel of fence to clear the plow with the wings open. It facilitates repairs to have the guard inside the rails in two sections, rather than one, as then the whole guard need not be taken up to repair a broken slat or to make room for tamping one side of the track, in case it gets out of surface. One manner of holding the slats together in sections is by a 1x6-in. cross piece at each end of the section, gained into the under side of the slats, securing each slat to the cross piece by a ½-in. bolt. Another cross piece should be nailed to the under side of the slats at the middle of the section. These details are shown in Fig. 429. If the cattle guard was to exceed 12 ft. in length it would undoubtedly be best to have it made in two sections, lengthwise. Another method of holding the slats together is to separate them at proper intervals by spacing blocks at each end and pass a ⅝-in. bolt across the section, through both slats and spacing blocks. The sections may be held to the track by spiking the cross pieces to the ties or by track spikes driven into the ties with the heads hooking over the edges of the slats, or by lag screws. The use of lag screws permits the guard to be readily taken up. On some roads cattle guards are taken up during the winter season.

Wooden slats are usually triangular in section and are made by ripsawing diagonally across the corners a scantling 3 or 4 ins. square; or, if it is desired that the slat should have vertical sides for a portion of its depth, a stick of oblong section may be ripped diagonally through the middle—as, for instance, a 2x6-in. piece, which might be ripped into two slats, each 2 ins. wide, 4 ins. deep on one side and 2 ins. deep on the other, the bottom half of the slat section then being 2 ins. square and the top half triangular, 2 ins. wide and 2 ins. high. Strips of 1-in. board set edgewise between spacing blocks, with the top edge of the board beveled, and slats of square cross section set on corner into triangular notches sawed into the end cross pieces half the depth of the slat, are also used to a considerable extent. Oak and hard pine are much used for slat material. Figure 429 shows a typical wooden slat cattle guard, with another form of slat that is commonly used. The slats are yellow pine 3x5 ins. x8 ft. long, and the ends of the sections are fastened to 8x8-in. x12-ft. yellow pine pieces laid in place of the ties. As used on the Wabash R. R. a coat of tar is applied hot. A slat guard across the midway of a double track is usually laid on ties placed between the tracks.

Metal Cattle Guards.—Metal surface guards have slats of various forms. The National guard has, in one form, flat metal slats serrated and barbed, set on edge and fitting into slotted cross pieces of triangular section, at the ends and at the middle. Alternate slats are 2½ and 3½ ins. deep and the slats are spaced from 2¾ to 3¾ ins. apart. Another form of this guard has slats of angle iron, with the angle placed uppermost, or like an inverted V. The Kalamazoo cattle guard has triangular slats, alternating with rows of triangular teeth that do not extend quite so high as the triangular slats, the idea being that an animal's hoof will slip down upon the teeth, but a person falling upon the guard would (if he fell across the slats) not strike the teeth. The guard consists of four sections of steel plate stamped into inverted V-shaped ribs alternating with flat surfaces out of which the triangular-shaped teeth or tongues referred to are struck up. The triangular ribs are spaced so far apart that the hoofs of stock cannot reach between two, but must slip down upon the teeth. The ends of the ribs are sloped off by bending down a piece of the metal. The Bush cattle guard has slats of inverted T-irons 2 ins. apart held in slotted pressed steel cross pieces of triangular section. The Merrill-Stevens cattle guard has slats of 1¼x1¼-in. T-irons set at a slant, so as to present an upturned edge. One design of the Standard cattle guard has Z-bar slats set at an incline so as to present an upturned corner. In another style of this cattle guard the slats are angle bars with one leg much longer than the other, and it is laid with the long leg inclined to the ties and overhanging the upturned short leg of the next bar. The bars are arranged in sections with spacing plates and cross bolts, and the ends of the slats are beveled down to prevent dragging things from catching.

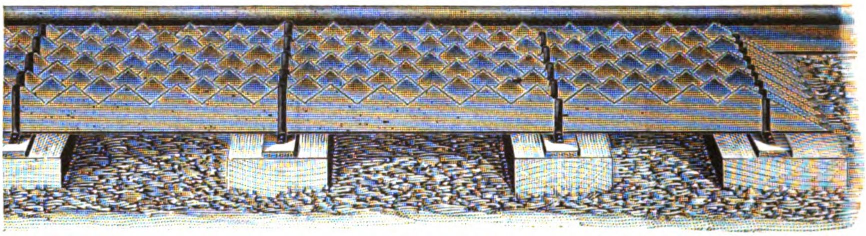


Fig. 430.—The Cook Cattle Guard.

The Cook cattle guard (Fig. 430) consists of serrated steel slats in four interchangeable sections of nine slats each, resting upon metal cross pieces of channel section spiked to the ties. The teeth in adjacent slats are alternated, so that the point of a tooth in one slat is directly opposite the space between two teeth on the adjacent slat, thereby presenting an uneven and unstable footing for stock. The teeth are sufficiently pointed to inflict punishment without cutting deep enough to cause serious injury to animals stepping or falling upon them. The slats are held in position by looped irons or fasteners bolted to the back of the channel cross pieces. For securing these sections to the ties spikes may be driven between any of the slats. A special attachment which may be used in connection with this guard is an intermediate slat for turning hogs and other animals with feet small enough to pass between the main slats. It is lower than the main slats and has small teeth projecting alternately from side to side, after the manner of set in a saw. These auxiliary hog slats are placed between the main slats at the end toward the highway, being fastened by bolts passed up through the cross channels. The chain cattle guard has rows of link-belt chain stretched parallel with the rail over suitable cross pieces at intervals.

The Sheffield cattle guard (Fig. 431) is formed from four sheets of annealed steel plate, each 26 ins. wide, from which 3-in. triangular teeth are struck up 3 ins. apart, in rows 3 ins. between. The sections are spiked flat on the ties without preparation of the latter, and there is no chance for dragging brake gear to catch the plate and tear it out. Being of soft steel the teeth, if bent by accident, can be straightened up by driving with a spike maul. The sections are made in lengths as ordered. The Walhaupter and Positive cattle guards are similar and are formed of buckled plate with folds running crosswise the track and reaching to the bottom of the ties, the pitch of the folds or corrugations corresponding in length to the spacing between the ties. These folds are shaped something like the teeth of a ratchet, and, as laid down in the track, there is an inclined surface running from an upper corner of each tie to a lower corner of the next tie, so that, when an animal steps upon it the hoof will slide into the fold and strike against the ridge or upper corner of the adjacent fold, and thus the leg meets with an obstruction just above the ankle which prevents the animal from stepping forward. The Trackman's cattle guard (Fig. 432) accomplishes its purpose in the same manner, but the folded metal is made in separate pieces, one of which is spiked to each tie. The ties are spaced 12 ins. apart in the clear and the ballast is removed even with their bottoms. The object in making the guard in small pieces is to facilitate removing ties for renewals, to permit lining or surfacing of the track without taking the guard apart, and to avoid the ripping up of a large sheet of metal in case some parts should be torn loose. Iron cattle guards in large sections have been known to tear loose, get under the wheels and cause train wrecks. As will be noticed in the sectional view, there are three different shapes, one being next the highway, another at the opposite end, with several pieces on the intermediate ties that are of the same shape.

The Chicago, Rock Island & Pacific Ry. has in use a number of barbed wire cattle guards designed by Roadmaster J. D. Sullivan. The strands of barbed wire in each section of the guard are stretched over a frame made of two strips running parallel with the rails, with four cross pieces of wood of triangular section, covered with sheet metal. The ends of the section are held together by bolts and the barbed wires are woven back and forth from end to end of the section, on lines parallel with the track. This guard is used on parts of the road in Indian Territory and northern Texas, where the cattle are hard to hold and where other forms of surface guard have failed. The guard was illustrated and described in the Railway and Engineering Review of July 17, 1897. In some quarters it is the practice to cover wooden slat guards with strands of barbed wire stretched over or interlaced between the slats, to frighten the animals away. From the appearance of some such affairs after a dragging brake beam has struck it one would think that it surely would frighten either man or beast, if anything could.

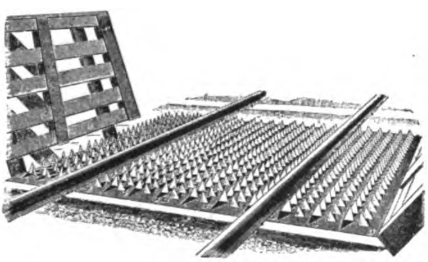


Fig. 431.—Sheffield Cattle Guard.

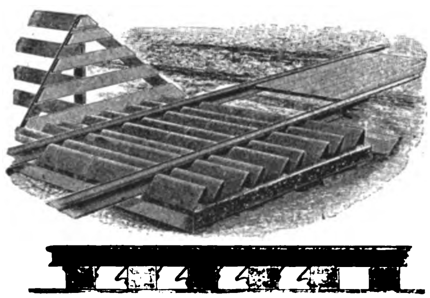


Fig. 432.—Trackman's Cattle Guard.

The Climax cattle guard consists of blocks of vitrified shale clay 24 ins. long, 8½ ins. wide and 4½ ins. high. Each block is formed of two longitudinal triangular ridges molded in shells 1¼ ins. thick and united at the base. The blocks are arranged in rows and held in place by means of a 2-in. wooden cleat around the guard. The end blocks are beveled and slotted for spikes. The complete guard is composed of 40 blocks and weighs about 1200 lbs. There is also a style of cattle guard consisting of rows of drain tile standing vertically on end between the ties and left empty. The top of the tile comes at about the level of the top of rail and each tie is covered with a triangular stick of timber.

Cattle guards are as numerous as Yankee ingenuity has been able to devise, but only a comparatively small number of the inventions in this line have succeeded in being put to use. One idea which inventors seem to persist in working at employs a gate or other barrier which normally lies flat in the track, but is flipped up like a jumping jack in the face of the animal, which is supposed to put the concern in motion by stepping upon a plank or treadle of some kind lying between the ties. Just what would become of such a piece of apparatus if it was flipped up in response to a dragging brake beam may be readily imagined.

The highway or wing fence which is brought across the right of way, and terminated on either side of the cattle guard, should meet the guard with a leaning panel or "apron fence" which is fully as long as the guard; and this panel should be so substantially built that it cannot be hooked down. Animals will jump or "angle" themselves around a short triangular panel or A-fence, which not infrequently constitutes the apron fence of the guard, as shown in Fig. 432. The correct way to build this panel is shown in Fig. 431. The leaning panel should foot at the guard, and it may consist of boards nailed to leaning posts, or the posts may be set plumb and support the panel by brace pieces nailed to the panel battens. At all events there should be post supports at the ends of the panel, and the bottom of the panel should not be fastened to the ties or to the guard, as the jarring of the ties would soon work it loose. All cattle guards should extend squarely across the track, whether the fence joining the guard approaches the track at right angles or diagonally. Leaves, in the fall of the year, and pieces of waste, if allowed to accumulate in a wooden pit or surface guard, make good kindling and increase very much the liability of destruction by fire. But the effectiveness of a surface guard, of either metal or wood, is much better maintained if it is kept cleared of rubbish. Weeds should not be permitted to grow in cattle guards.

The wing fence and the leaning panels at a cattle guard should be whitewashed. Aside from the fact that such treatment may increase the effectiveness of the guard, the white fence is conspicuous at night and assists enginemen to readily locate themselves. The most common mixture for whitewash for railway fences is salt and air-slaked lime, the salt being generally used in the proportion of one tenth the quantity of the lime. It is considered advantageous to permit the lime to slake several days before using it. The Chicago Terminal Transfer R. R. uses white glue and whitewash, and on second application finds that it will last about one year. The mixture consists of 5 lbs. of glue to each barrel of lime. Another mixture that is sometimes used consists of 100 lbs. of cement to each barrel of lime, allowing the lime to slake 30 days before using. Salt and boiled rice mixed with lime is still another mixture that is used for a whitewash. A half bushel of lime is slaked in water and covered to keep in the steam. To this is added 4 quarts of salt dissolved in warm water, and then 3 lbs. of rice ground and boiled to a thin paste, while still boiling hot, is stirred into the whitewash. A mixture that is used on government buildings and light houses consists of ½ bushel of lime, 8 quarts of salt and 3 lbs. of ground rice treated in the foregoing manner, to which are added ½ lb. of Spanish whiting and 1 lb. of glue previously dissolved in water. After adding 5 gals. of hot water the mixture is allowed to stand for a few days covered from dirt. When used it is heated and applied hot. The Grand Rapids & Indiana Ry. uses a locomotive and car equipped with air compressing machinery and spraying devices. This outfit is in service for all whitewashing along the right of way, including fences, cattle guards, etc.

One thing which conduces to the effectiveness of cattle guards is to keep stock from becoming familiar with them, and to do this obstacles may be placed in the way of walking up to the guard and which will make it inconvenient to stand around them. On general principles it is also desirable to prevent stock from standing on or near the track in the vicinity of road crossings. A plan that is sometimes followed with this end in view is to put the cattle guard a little way back from the road and then cover the track and roadbed on the highway side of the guard with some material that will make the footing insecure. The Union Pacific R. R. uses coarsely broken slag in such places. Such may also be used for a "bicycle guard" in towns and cities, where people are inclined to use their wheels on the shoulders of the roadbed or in the midway between tracks. In this case it will usually suffice to merely strew the ground with the lumpy material for some distance from the crossing.

The usual practice is to bring the wing fence up to the middle of the guard or to the highway end of the same, but some careful observers of the behavior of stock in the vicinity of cattle guards claim that the efficiency of the guard is improved by running the fence up to the end of the guard or guard panel which is farthest from the highway crossing; in other words by putting the cattle guard all on the highway side of the wing fence. The explanation is that when cattle are feeding or wandering along the wing fence and headed toward the track, they meet with an obstruction which will direct their attention away from the track instead of presenting an opening into which curiosity might lead them; and also, when cattle standing upon the crossing become frightened by the approach of a train, the guard and side panels, standing out in front of the highway fence, as they do, appear to the animal like a shelter, behind which they will dodge, instead of making a rush for the opening, as they are likely to do where the end of the guard nearest the highway is flush with the wing fence.

153. Bridge Floors.—The bridge floor is where the track and bridge departments meet. Although the construction and maintenance of bridge floors are placed in charge of the bridge department, the rails and fastenings are subject to inspection and repair by the track forces; and as the design of the floor has a great deal to do with the safety of the track, under certain circumstances, the subject may properly be considered in a treatise of this character. The bridge floor may be defined as that portion of the supporting structure which is added to the naked trusses, girders, or trestle bents with their necessary bracing, to support and protect the track and properly distribute the load to the trusses, girders or main supports. The component parts would then include the ties, guard rails, guard timbers, floor beams, and stringers, if the last mentioned are used. As the floor beams and stringers constitute the foundation of the floor, the manner of their arrangement determines very largely the strength of the floor and may logically be considered first.

Floor Beams and Stringers.—The floor of trestle bridges is usually formed of sawed track ties resting across stringers supported by the caps of the trestle bents. This is about the simplest form of bridge floor and the one on which the designs of different railways vary the least. In wooden trestles the spans are usually 12 to 16 ft. and there are usually three stringers placed directly under each rail, or nearly so, a common size of stringer for spans of 16 ft. being 8x16 ins. On some roads only two such stringers are used under each rail. The stringers under each rail are usually spaced from 2 to 4 ins. apart, bolted together through spacing blocks or spools, to maintain air space, and to prevent them from shifting sidewise one of the stringers is bolted to the cap, a long bolt sometimes being used which passes through cap, stringer and tie, and sometimes also through the guard timber. A drift bolt is also frequently used, either being preferable to the practice of spiking pieces of plank on top of the cap, as such will retain moisture and start early decay. In addition to the sets of stringers placed underneath the rails a side or "jack" stringer is sometimes used under or near each end of the ties, to support the ties outside the rail in case of derailment. Owing to the deflection of the main stringers and ties these side stringers are usually considered to carry a portion of the load, the distribution depending, of course, upon the amount of deflection in the main stringers and in the ties. On girder and truss bridges there is a considerable variation with the different roads, in the arrangement of floor beams and stringers, and although in a discussion of the various designs there is room for a great deal to be said, a condensed statement will serve to bring out the principal features of many of these designs. In preparing this I have consulted a very thorough report on "Bridge Floors" by a committee of the Association of Railway Superintendents of Bridges and Buildings in 1897. Some of the illustrations used were selected from a large number contained in that report.

In wooden through truss bridges the distribution of the floor beams may be effected in three different ways: they may be concentrated in sets at the panel points (*A*, Fig. 433); they may be uniformly spaced at short intervals (*B*, Fig. 433), thus permitting the use of smaller stringers; or the ties may bear upon the lower chord of the bridge direct, thus serving as floor beams (*D*, Fig. 433). When the last-mentioned method is resorted

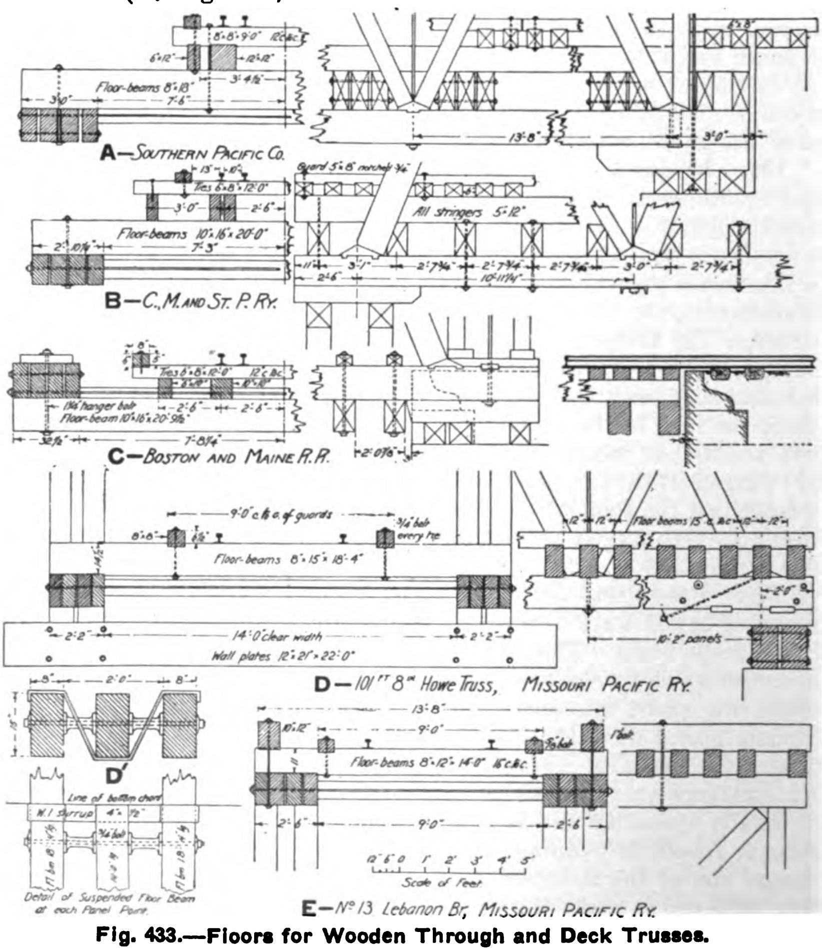
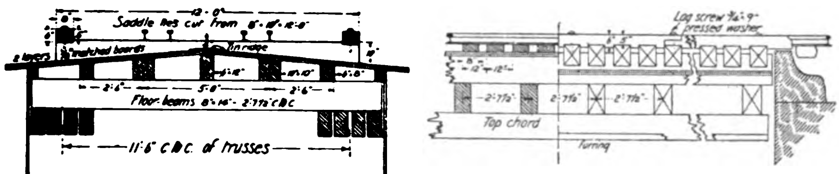
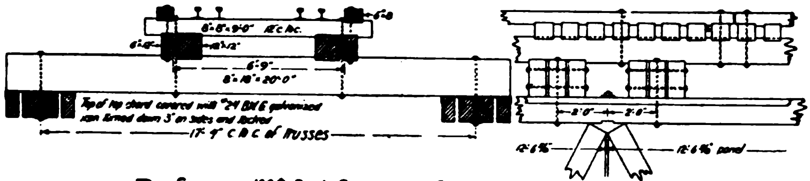


Fig. 433.—Floors for Wooden Through and Deck Trusses.



A—*Epping Bridge*, BOSTON AND MAINE RAILROAD

Scale of Feet



B—*Standard 100' Deck Span*, SOUTHERN PACIFIC CO.

Fig. 434.—Floors for Wooden Deck Trusses.

to ties which come opposite the panel points must be cut off short and supported in some manner upon the adjacent ties. One method of obtaining such support is shown by Engraving D′, Fig. 433. A wrought iron stirrup formed from a bar 4 ins. wide and ½ in. thick supports the tie at each end and is hooked over the tops of the two adjacent ties. The tie is securely held to its proper spacing by bolts and separating spools and an 8x8-in. guard timber is bolted to every tie, which also aids in distributing the load over the ties. When the floor beams are supported directly upon the bottom chord the deflection of the beam under load brings an undue proportion of the load on the inner edge of the chord. One method of alleviating this trouble to some extent is to arrange for carrying a portion of the load upon side stringers, thus reducing the deflection of the beam. By hanging the floor beam below the chord the load may be distributed over the whole width of the chord, the beams can be distributed without interference from the braces or posts at the panel points, and there is effected a gain in headroom over the track equal to the depth of the floor beam plus the depth of the chord. The method of suspending floor beams from the bottom chord in practice on the Boston & Maine R. R. is illustrated by engraving *C*, Fig. 433. With suspended floor beams, however, the lateral bracing of the trusses rests upon the top of the beams, thus necessitating the cutting of the stringers where these members cross. Such cutting or notching necessarily weakens the stringers, and for this reason suspended floor beams are usually distributed uniformly, so as to relieve the stringers of the bending moments which they would necessarily have to undergo if supported on floor beams concentrated at the panel points.

On wooden pony trusses the floor beams may be either supported upon or suspended from the lower chord, but the design of the floor may somewhat affect the manner of bracing the top chord. The top chord is usually braced from the outside by a leaning strut footing into a collar beam suspended from the bottom chord. If the floor beams rest upon the bottom chord the collar beam is independent of the bridge floor and there is consequently no interference. Likewise, if the floor beams are suspended from the chord the collar beam must be made independent of the bridge floor, else the deflection of the floor will carry the collar beam down with it and operate to throw the top chord out of line. One method of avoiding such trouble is to block the collar beam against the under side of the chord so as to be clear of the stringers of the bridge floor. On wooden deck trusses the ties may rest directly upon the top chords (Engraving *E*, Fig. 433), or they may be laid upon stringers supported on floor beams concentrated at the panel points, as in the case with the Southern Pacific bridge shown by Engraving *B*, Fig. 434.

With track supported by columns and I-beams there is the usual arrangement of main and side stringers, as with trestle bridges. With deck plate-girder bridges there are usually two girders under each track, the girders being spaced 6 to 9 ft. centers, the spacing depending largely upon length of span and depth of girder. Engraving *B*, Fig. 435, shows the usual method of construction, the ties acting as floor beams. On widely spaced girders the deflection of the ties under load brings a heavy bearing upon the inner edge of the top flange of the girder, tending to bend the flange and spring the web plate. Engraving *D* shows a method of concentrating the load at the center of the flange, as practiced on the Chicago, Milwaukee & St. Paul Ry. The standard deck girder bridge of the Boston & Maine R. R. (Engraving *A*) has girders spaced at 9 ft. centers with floor beams and iron stringers between, the top of the stringer coming even with the top of the girder, so that the latter acts as a side stringer for supporting the ends of the ties. The lateral bracing is confined to one system, which is placed in the plane of the bottom flanges of the floor beams. The simplest form of floor for through plate girders is shown as Engraving *A*, Fig. 436. The ties act as floor beams and are supported upon the bottom angle or flange of the girder. This method of support has a tendency to weaken the flange, and the lateral bracing and the ties interfere with each other with detrimental effect to the latter. This trouble is overcome by the use of a "shelf angle," which carries the ties clear of the bracing, as shown on the Nashua and Acton bridge, Engraving *E*. In some places plate girders are so closely spaced that the necessary clearance cannot be obtained to use them as a through structure, and the allowable depth will not permit a deck structure. In

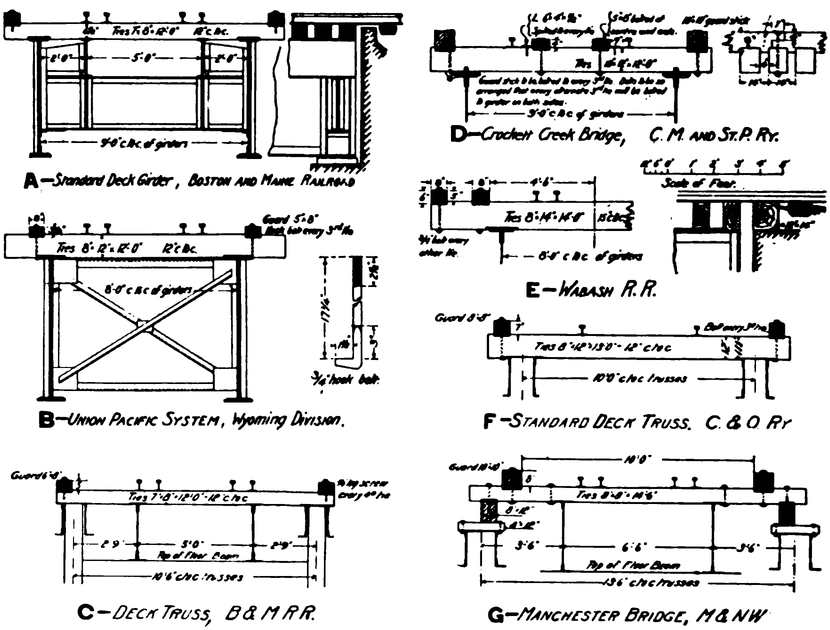


Fig. 435.—Floors for Plate-Girder and Iron Truss Deck Spans.

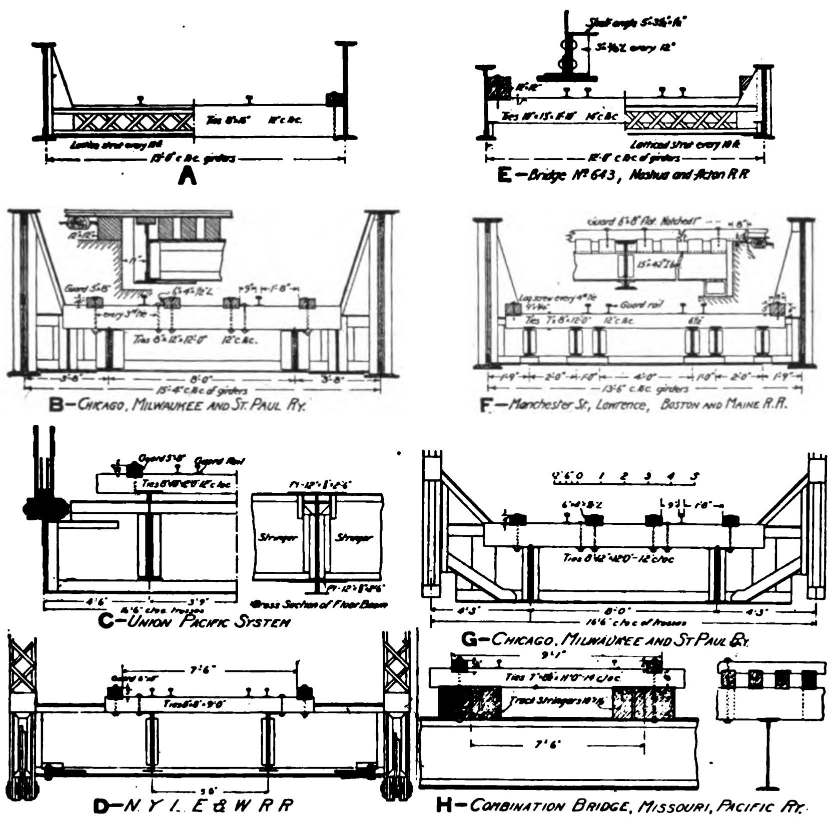


Fig. 436.—Floors for Iron Through Girders and Trusses.

that case the ties can be laid upon shelf angles riveted to the webs of the girders at such a hight that top of rail will come even with the top flanges of the girders. Such is the construction of some of the bridge floors of the Chicago, Milwaukee & St. Paul Ry. In the Chicago, Milwaukee & St. Paul bridge shown as Engraving *B* there are two plate-girder stringers heading against the floor beams, and the ties are arranged as upon a deck girder. The introduction of floor beams and stringers shortens the span of the tie and reduces its size. Engraving *F* shows a method of support with side stringers, in use on the Boston & Maine R. R.

In iron through truss bridges there are usually two iron stringers for each track spaced 5 to 8 ft. apart and headed into the floor beams. In some cases, however, both main and side stringers are used, all of the stringers heading against the floor beams. The floor beams are sometimes hung from the pins at the panel points and sometimes they are riveted to the posts. As a usual thing the stringers heading against the floor beams are supported upon the bottom flange of the floor beam which, being of greater depth than the stringer, extends into the space between the ties and sometimes within a few inches of the top of tie or rail base. In such cases the tie spacing must be modified slightly to make room for the upper flange of the floor beam, but as the interval is not great there is no serious objection. On the Union Pacific bridge shown by Engraving *C*, Fig. 436, the stringers project above the top flange of the floor beam and are connected across the space over the floor beam by a 12x⅜-in plate 2 ft. 6 ins. long. Engraving *H*, Fig. 436, shows a combination wood and iron floor in use on the Missouri Pacific Ry., in which wooden stringers are used upon plate-girder floor beams.

On iron deck trusses the ties may be used as floor beams and rest directly upon the upper chord. As in the case with wooden deck trusses, some bridge engineers object to such practice on the principle that the upper chord of the truss is designed primarily as a compression member, and not as a beam, and that a load bearing upon the chord between panel points subjects that member to an excessive burden, unless it is designed especially heavy for the two duties it must perform. Engraving *F*, Fig. 435, shows this method of support. Engravings *C* and *G* illustrate forms of construction in which iron girder stringers and floor beams are used, the latter being riveted to the posts, and the top chords acting as side stringers. In the form shown by Engraving *G* the lateral bracing is arranged in the plane of the bottom flange of the chord and the top flange of the floor beam, while in Engraving *C*, in which a greater depth of truss is utilized, the bracing is attached to the top flange of the floor beam, some distance below the chord. The latter arrangement is somewhat objectionable, from the fact that the lateral bracing at this point may cause bending of the post. The simplest and perhaps the best form, if the depth can be spared, is to rest the floor beams on the top of the chord at the panel points and head the stringers against the floor beams.

The arrangement of placing the stringers between the floor beams on an iron bridge makes a stiffer floor than is to be had by supporting the stringers on top of the beams. A secure way of making the connection between floor beams and iron stringers which abut against them is to rivet on a pair of vertical angle irons through the web at each end of the stringer and then rivet these angle irons to the web of the floor beam. Where stringers are headed into both sides of a floor beam, as at any of the intermediate panels, the angle connections on both sides of the floor beam may then be riveted to the web of the same, through and through. An efficient way to arrange lateral bracing, where the conditions will permit, is to rivet angle irons to the ends of the floor beams or to the chord members and pass them diagonally under the track stringers, riveting to the bottom flanges of the stringers wherever the two cross.

Wooden stringer pieces are usually two panels or two spans in length and are laid to break joints over the caps or floor beams. A lap stringer is one composed of pieces whose ends overlap each other on the caps or floor beams. Owing to the predisposition of timber to decay where surfaces in contact are exposed to the weather, it is not considered the best practice to have stringer timbers abut squarely, if they meet end to end. Where this rule is observed the stick is cut off slightly out of square at the ends, so that the two pieces abut against each other at the top, or for an inch or two down from the top, but are separated by an air space of $\frac{3}{8}$ or $\frac{1}{2}$ in. at the bottom, where they rest upon the cap or other support and where it is highly desirable to preserve the timber in sound condition as long as possible. Where stringers are packed together in sets they are sometimes spliced at the panel points by pieces of plank about 6 ft. long bolted either upon the outside or between the pieces, thus serving the additional purpose of spacing blocks. To prevent contact between the wood surfaces the splice pieces are separated from the stringer timbers by cast iron washers. On the Elgin, Joliet & Eastern and West Shore roads these splicing planks extend an inch or two below the bottoms of the stringers and are notched over the cap. In addition to this the West Shore road secures each stringer timber to the cap by a drift bolt. It is well to note in passing that iron spools or washers, being non-retentive of moisture, are superior to wood blocks for spacing pieces. Corbels are used to some extent with stringers. The width of the corbel is made the same as that of the stringer, the depth 12 or 14 ins. and the length about 4 ft. The corbel affords the stringer a larger bearing surface than it would get if it rested directly upon the cap, and for this reason there is possible a longer use of the stringer after decay starts at the end than would be the case without it. It also stiffens the stringer and in effect reduces the span. It is used mostly where the span exceeds 16 ft. It is said that in spans of 18 to 20 ft. the use of the corbel will decrease the deflection from 25 to 30 per cent. In iron trestles the longitudinal girders or stringers are sometimes headed against and riveted to the webs of the columns. In some cases where such a connection is made with a column that stands at a batter, the column is bent just below the junction with the stringer, to bring the top part vertical.

As the primary office of the bridge floor is the proper distribution of the load upon the trusses, girders or trestle bents, the foregoing methods of arranging floor beams and stringers may be considered applicable to bridges of all classes, regardless of the character of the immediate support for the track rails. With respect to the immediate support for the track, bridge floors may be divided into two classes: open floors, where the rails are carried upon timber cross ties supported upon stringers or upon the top chords or flanges of the spans; and solid floors, where the ties are underlaid by a tight floor of some kind, the rails resting directly upon the floor covering or upon ties, with or without an intervening layer of ballast. The type of floor in most general use is the open floor, which will be considered first.

Bridge Ties.—The size of tie required for a bridge floor depends upon the manner in which the tie is supported. If the tie is supported by stringers directly under the rails, or nearly so, it supports the rail without appreciable bending moment, and other than this its duty is merely to hold the rails to gage and in line. Under such requirements a tie of ordinary size is sufficient, and the common sizes are 6x8, 7x8 and 8x8 ins., the first and last mentioned being the most common. If, however, the tie is called upon to act as a beam it must be proportioned for the span, and in some cases a large piece of timber may be required. There is also the important difference that ties supported by stringers directly under the rails may safely remain in the track as long as they are sound enough to hold the spikes well, whereas if the stringers come outside the rails the renewing of the ties must be looked after more carefully and the life of the tie is legitimately shortened. Twelve feet is a common length for a bridge tie supported upon stringers. They are frequently used as short as 9 ft. but it is desirable that they should be long enough to permit setting jacks and laying blocking in case a derailed car should come to a stop on the bridge. On double-track bridge floors a long tie (22½ to 24 ft.) running under both tracks is sometimes used, but this arrangement meets with the objection that in renewing ties both tracks must be disturbed simultaneously. It is therefore considered better practice to use independent sets of ties for the two tracks. Ties 12 ft. long will usually close the gap between the tracks on a double-track bridge. On trestles the ties should extend out far enough to cover the caps, so that in case a derailed car should fall off the trestle it will not strike a cap and knock out a bent. White oak, yellow pine and fir are the woods most used in this country for bridge ties and floor timbers.

The ties in a bridge floor must be made secure against being moved out of line and also against being spread apart or "bunched" under derailed wheels. The proper alignment of the ties may be maintained by dapping them over the stringer or by drift-bolting a portion of the ties to the stringer, if the latter be wood; or by securing them to the stringer with hook bolts (Engraving *B*, Fig. 435), if the stringer be of iron or steel. Bolts and nuts are also commonly used for securing ties to wooden stringers. It is also quite largely the practice, where the stringers come directly under the rails, or nearly so, to lay the ties on flat, except every third or fourth tie, which is turned edgewise and dapped over the stringer to bring its top level with the other ties; and sometimes ties of extra depth are provided for this purpose, in case all of the ties are laid on edge. Another method somewhat in vogue with ties laid upon built girders is to notch each tie over a projection of the web plate through the upper flange of the girder, as shown in Engraving *D*, Fig. 435, and Engraving *B*, Fig. 436. For holding the ties in line it is usually thought to be sufficient to dap them over the stringers or girders ½ in., but in certain localities the use of bolts or hook bolts in addition is recommended as a means of preventing the ties from being blown off the bridge by heavy wind or lifted off by high water. A long "deck bolt" passed through the cap and a tie, on the center line of the track, at each bent, is sometimes used. Ties laid upon plate girders may be brought to an

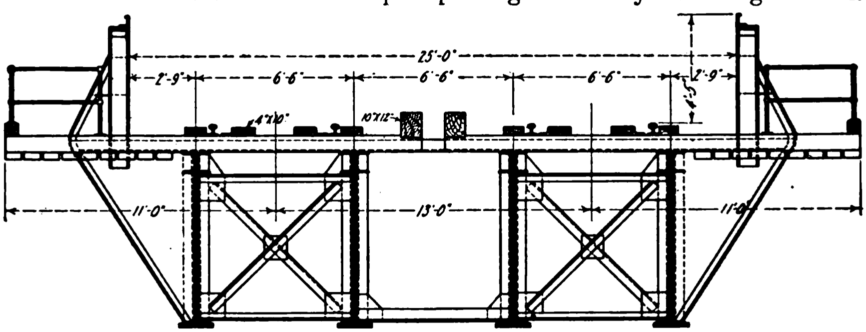


Fig. 437.—Cross Section of Floor at Hand Car Refuge, Boone Viaduct, C. & N. W. Ry.

even bearing for the rail by notching deeper into those which come at the middle portion of the span, to allow for the extra thickness of cover plates. In order to provide a smooth bearing surface for the ties—that is, one without rivet heads—and to avoid the necessity for dapping the ties to allow for varying thickness of the girder flange, it is now quite extensively the practice to dispense with cover plates altogether for the top flange of plate girders. The necessary strength is then provided by a "double flange," consisting of two lines of angles on each side of the web, with perhaps side plates besides. The plate girders shown sectionally in Fig. 437 are built this way.

Ties are made secure against bunching under derailed wheels by spacing at close intervals and dapping the guard timbers 1 to 1½ ins. over them, so as to have a joggle or blocking between each two ties. The clear spacing between ties is made as little as 4 ins. in some cases, but more generally about 6 ins. A space as small as 4 ins. is liable to catch a workman's boot and it leaves a weak joggle on the guard timber for holding the ties to their spacings. The guard timber is bolted to every third or fourth tie (in rare cases to every tie), preferably over the side stringer, in case such is used. A long bolt can then be passed through the guard timber, tie and stringer. In order to prevent the bolt from splitting the tie it is the practice with some to let the tie project 4 to 6 ins. beyond the outside of the guard timber For fastening guard timbers to the ties both bolts and lag screws are used, but in oak timber it is found that the thread of lag screws is rapidly eaten away, so that the bolt and nut proves to be a much more reliable fastening for such timber. In yellow pine timber, however, such is not the case, and lag screws are frequently removed and used the second time. The best practice seems to favor putting the bolts into the timber from underneath, so that the nut comes on the upper side, in plain view, and where it can be readily attended to in case it should work loose. With nuts put on above the timber, however, the hole through the wood cannot be so well protected from water as when the nut is put on from below. To prevent the head of a lag screw or bolt from projecting above the timber it is sometimes countersunk into the timber by the use of a cup-shaped washer. To prevent the bolt from dropping out, in case the nut on the upper end should work off, some make it a practice to bend the bolt slightly before it is driven into position. This trouble is overcome, however, by the use of a slotted washer. This is a cast washer of the ordinary form with a slot extending radially from one side of the hole, so that after the nut has been screwed home a nail can be driven through the slot and against the side of the nut, thus serving as an efficient nut lock.

Guard timbers are usually spliced over a tie with a scarf or half-and-half joint, with at least a 6-in. lap, as shown by Engraving *D*, Fig. 435; or sometimes the two pieces are butted together squarely and bolted through adjacent ties, as shown in Engraving *B*, Fig. 434. In usual practice the pieces of the guard timber are made to break joints with the stringers—that is, the middle of the stick comes over the bent or floor beam and the pieces are halved together at the middle of the panel. Another idea is to have the joints in the guard timbers on opposite sides of the floor come staggered. Guard timbers vary in size from 6x8 ins. to 12x12 ins., the smaller size being most frequently in use. A ¾-in. bolt is the size commonly used. The hight or projection of the guard timber above the level of the top of rail must be governed by the reach of the snow plows, in case the timber comes within clearing distance. The guard timber is sometimes placed within 9 ins. of the outside of rail, but more frequently the distance is much greater. The question as to the proper distance between guard timber and rail is taken up in connection with the subject of bridge guard rails.

On bridges of considerable length a string of planks or boards should be spiked to the ties for a footway. Trackmen and other employees must travel the bridge and the public will, and it is well therefore to make the walking safe. The walk is especially convenient for flagmen running to or from their trains, and it is most serviceable when the ties are covered with frozen sleet. If it is feared that stock might reach the bridge and use the walk, it should be omitted for some distance from the end of the bridge. On a double-track floor the walk comes between the tracks. On long trestles refuge platforms large enough to receive a hand car should be provided every 1000 ft., or ¼ mile at the farthest. Such platforms may be built by planking over long bridge ties extending out past the guard timber, over a bent, and bracketed against the bent. Figure 437 shows the general arrangement of hand car refuges on the Boone Viaduct of the Chicago & Northwestern Ry. This viaduct is 2685 ft. long and 185 ft. high at the highest point, and on each side of the viaduct there are four refuge platforms at an average distance of 537 ft. apart, arranged with a substantial railing, as shown. The brace which appears in the figure is for the support of the bridge railing, which is necessarily broken at the platforms.

If the track on the bridge is curved the running rails should be spiked to every tie; but on straight line there is no necessity for spiking more than half of the ties; i. e., alternate ties. To get the rails in proper alignment they should not be permanently spiked until after the guard timbers have been laid and bolted complete. As the grain of bridge ties does not always run parallel with the sawed faces, they should be bored for the spikes with a ⅜ or $^7/_{16}$-in. auger, to prevent splitting. No splice bars should be slot-spiked on bridge ties, because the ties cannot be moved by creeping rails and are therefore liable to be split by pressure against the spikes.

Tie plates are quite extensively used on bridge ties, particularly where the latter are of pine timber, and hard pine is now one of the standard timbers for bridge ties. They are also used on oak ties in some cases where the traffic is particularly heavy or where the bridge is on a curve. In point of economy it may in many instances be found advisable to use plates on bridge ties where they may not be needed on the adjoining grade ties. The first cost of the former exceeds that of the latter, and the cost of renewal is also higher.

End Construction.—The point at which the most trouble usually arises in maintaining track to surface at bridges is at the line which technically divides the bridge and the track departments, namely, at the abutment or the end bent. If the abutment be of stone or other firm foundation, the surface of the track approaching it must be well maintained, because a rough spot at such a place is more severe as a cause of jarring trains than elsewhere, owing to the different sustaining properties of the two materials

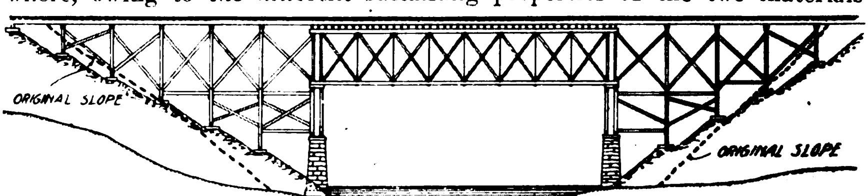


Fig. 438.

lying adjacent to each other; and if the abutment lies askew to the direction of the track the jarring due to uneven surface becomes much aggravated. If the end of the bridge be on timber, as at the end of a pile or framed-bent trestle, the effect of a low place in the track approaching the structure will be to create a heavy pounding force as the passing wheels suddenly mount the higher track at the proper level. Such pounding will settle the end bent if it be not very firmly supported. The importance of a bent of the full sustaining power at this point is therefore apparent. A fault too frequently met with is the want of some inclosure to hold the roadbed and ballast from being washed or crowded away from the end of the bridge, thus weakening the support for the track where it is most needed. But good end construction will not avail if the track immediately adjoining is not kept in good surface, neither can good surface be maintained where there is poor end construction. The question of maintaining smooth track at the ends of bridges, therefore, involves matters which concern both the bridge and the track departments.

With trestle bridges adjoining an embankment the earth usually slopes away for some distance under the trestle, or past the first two or three bents. A substantial bulkhead must therefore be provided to retain the ballast and roadbed at the point where the bridge floor joins the grade. Such a bulkhead is usually formed by spiking 3 or 4-in. planks to wing piles driven some distance out from the bent and slightly in rear of the line of piles in the bent. As it is desirable that an air space of 3 or 4 ins. should be maintained behind the cap and at the ends of the stringers, the bulkhead is separated from the end bent by furring strips spiked to the backs of the bent piles below the cap. The bulkhead should begin about 2 ins. below the base of rail and extend well into the bank, below the tops of the piles, so there will be no liability that material will be washed from under the bulkhead in time of high water or from the wash of surface drainage during a heavy storm. The outer edge of the bulkhead should conform to the slope of the embankment, and a brace is usually run along each sloping edge, from top to bottom, and to this the ends of the bulkhead planks are spiked. To re-enforce the end bent against the pressure of the earth at the back of the bulkhead, struts are run from the cap to the second bent, preferably to the ground line. Where the embankment joins a waterway and is liable to scour, a winged bulkhead, extending into the solid earth beneath the embankment, is made by spiking planks to the back side of wing piles set to give the face of the embankment a flare. In low bulkheads 4-in. sheet piling is sometimes substituted for horizontal planking.

Fig. 439.—Terrace Retaining Walls, Tennessee Central Ry.

Where trestles are built over steep slopes considerable trouble is frequently experienced in maintaining the footings. On newly made embankments the footings, unless very carefully prepared, will settle, and even when built on the natural ground the excavations for the foundations of the bents may leave the slopes between them so steep that they will not stand. A plan that has sometimes been followed with good satisfaction, both on steep natural surfaces and on new embankments, is to terrace the end slope in a manner to reduce the general inclination and permit the slopes between the foundations to be built to the angle of repose of the material. A diagram of such construction is shown in Fig. 438, in which the original slope is indicated by the broken line. In building such terraces the work of excavation is started at the top and the surplus material is cast over the ends and sides and worked toward the foot of the embankment. In planning work of this kind it is desirable to make the general slope easy enough to permit berms or footings $3\frac{1}{2}$ or 4 ft. wide, and still retain the natural slope of the material between the bents. Where this cannot be done it is sometimes the practice to face up the slope with a stepped dry rubble wall, to retain the loose filling and afford footings for the trestle sills. Some extensive dry walls of this kind (Fig. 439) were built in the construction of the Tennessee Central Ry., the general slope over the walls being $1\frac{1}{2}$ to 1. If the embankment or slope is composed of material like clay, with a tendency to slide, it is generally considered that the wisest plan to follow is to avoid excavating into the slope at all, but to build piers at the top and bottom of the slope, to grade, or a pier at the bottom and a pile foundation at the top, and bridge the space between top and toe of the slope with a single span. In locating a line through country where the topography is favorable to the scheme, some engineers aim to close the gaps at the ravines either wholly by embankment or wholly by trestle, so that the problem of building the latter over the slopes of newly made embankments does not arise.

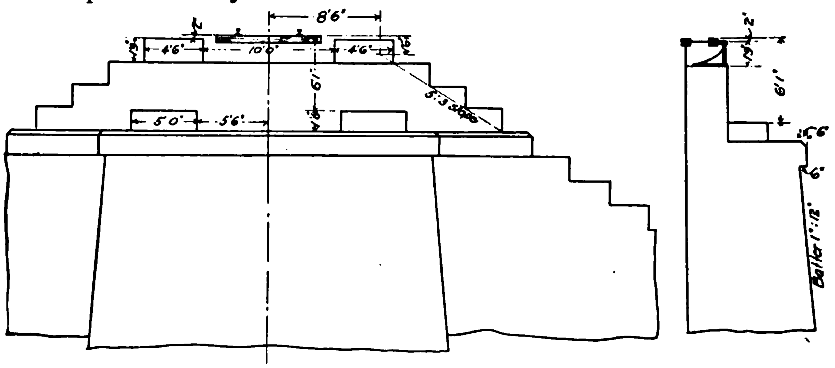


Fig. 440.—Arrangement of Parapets and Cast Iron Bulkhead, C., B. & Q. Ry.

On new embankments adjoining steel bridges the Chicago, Burlington & Quincy Ry. uses temporary spans supported upon piling driven into the bank. In order to avoid the construction of heavy abutments with wing walls to retain high embankments, the standard practice on this road is to place piers at the banks of the stream, with shore spans of plate girders supported temporarily at the bank ends upon timber blocking laid upon a foundation of piling. This pile foundation is located part way up the end slope of the embankment, and the piles are driven through the filling into the solid earth below the original surface. At the ends of the plate-girder shore spans temporary I-beam spans 16 or 17 ft. long are used, the bank end of each being supported upon a pile bent driven into the top of the embankment. After the embankment has settled a masonry abutment is built at the end of the plate-girder shore span, the short I-beam span is removed and the embankment is filled in behind the new masonry.

It is always important that the ballast under the first grade tie be retained in some substantial manner, and at the ends of bridges resting upon masonry the proper arrangement of the parapet requires careful attention. One method is to place a stick of timber, called a wall plate, on the parapet to support the rail, as shown in the Wabash bridge floor, Engraving *E*, Fig. 435. The objection to this practice is that the ballast lies against the timber, causing it to rot out quickly, and, besides, if the timber is not held rigidly in place by some means it will keep working its way over the edge of the parapet and permitting the ballast behind it to give way and settle under the adjacent ties. On the Boston & Maine R. R. the parapet stone at the top is narrowed down to about 8 ins. in width and extends within $1\frac{1}{2}$ ins. of the base of rail, so that the space between the last bridge tie and the first grade tie need not be uncommonly wide. This parapet (Engraving *A*, Figs. 434 and 435) serves to retain the roadbed and hold the ballast from being shoved out of place by the grade ties, so that the bridge floor and the track on the grade are separated by a distinct line without the intervention of anything which can decay or which is liable to be disturbed. In through bridges the end floor beam is usually dispensed with and the stringers supported upon the masonry direct. In some cases this arrangement permits of a closer spacing between the last bridge tie and the first tie on the ballast.

For masonry abutments cast iron bulkheads are used to good advantage, being durable and narrow, thus permitting close spacing between the last bridge tie and the first tie on the ballast. The standard bulkhead of the Chicago, Burlington & Quincy Ry. is a cast iron plate 21 ins. high and $\frac{5}{8}$ in. thick, bolted to brackets made fast in the masonry on the land side of the plate. On the backing, in rear of the bridge seats (Fig. 440), there are two parapets of masonry $4\frac{1}{2}$ ft. long and 1 ft. 9 ins. high, serving as enclosures at the ends of the bulkhead. The space between these parapets is 10 ft. in the clear and the bulkhead is made to fit into this space. The plate or face of the bulkhead is in two sections, each 5 ft. long, bolted to brackets at the ends of the bulkhead and to a third bracket in common, at the middle. The brackets are secured to the masonry by 1-in. stone bolts, two being used on each bracket, or six for the bulkhead. The plate is ribbed, bottom and top, the bottom rib being $4\frac{1}{2}$ ins. wide and the top rib, forming the top edge of the bulkhead, $3\frac{3}{4}$ ins. wide,

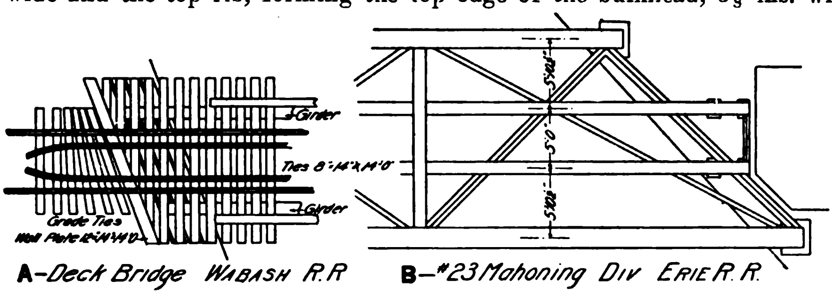


Fig. 441.—End Construction for Skew Bridges.

thus occupying but little room between the ties, so that a suitably narrow spacing may be had, as above noted. The top rib comes 2 ins. below the base of rail, so that a tie may be laid as close to the bulkhead as is desirable. At double-track bridges the arrangement is simply duplicated, two bulkheads being arranged with a common parapet between them. Figure 208 also shows a sectional view of this bulkhead.

At the ends of skew bridges the stringers should be arranged to meet the roadbed squarely (Engraving *B*, Fig. 441). The necessary support for the end of the extended stringer is usually afforded by a buttress at the back side of the masonry pier or abutment. Where this cannot be had, or is not provided, one of the stringers is sometimes extended past the masonry to meet the other squarely and is rested upon a mud sill. A few ties must then be supported partly upon the bridge floor and partly upon the embankment, and it nearly always happens that the projecting stringer or mud sill must be raised and blocked up occasionally to bring the track to surface; and besides, either piece of timber will rot out rapidly. The practice of ending the bridge floor at a skew and fanning out the ties on the roadbed (Engraving *A*, Fig. 441) to meet it is never satisfactory, since on one side of the track the ends of the ties must be spaced too close for efficient tamping and on the bridge floor the ties must be placed either askew to the rails or the last three or four ties must be cut short and joined into the wall plate (Engraving *A*), thus supporting only one of the rails. If the bridge ties are laid parallel to the parapet, or askew to the rails, both ends of the tie do not receive the load at the same time, and as a result the ties tend to jump and wear out rapidly. Since in passing from ballasted track to a bridge floor there is a change in rigidity of support, both wheels of an axle should pass the dividing line simultaneously, and hence the end of the bridge floor should be squared up with the track. In skew trestles the end bent can be built square or a square bent may be built immediately in rear of it to support the ends of the floor stringers. When a skew bridge is rebuilt upon old abutments the additional masonry necessary for supporting the ends of the floor stringers to bring them square may be laid upon the old bank by digging down and giving the new masonry a base of suitable size.

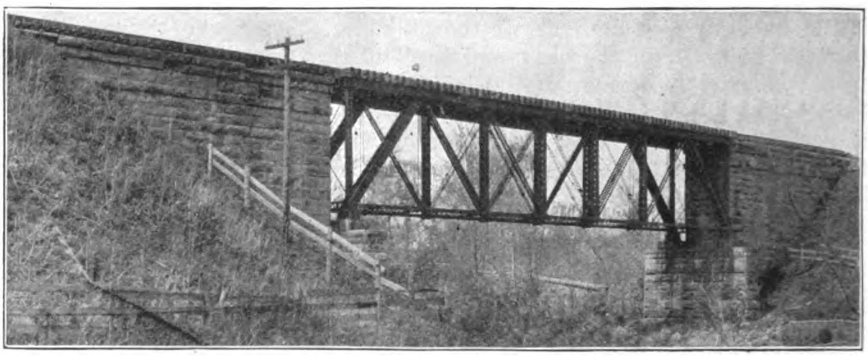


Fig. 442.—"T" Type of Bridge Abutment (Dismal Creek, Ill. Cent. R. R.).

With the "T" abutment style of end construction, examples of which may be seen on a number of roads, wing walls for retaining the embankment are dispensed with and the track adjacent to the bridge floor is very firmly supported. This type of abutment consists of a narrow masonry pier (Fig. 442) longitudinal with the track, extending back full depth into the embankment, from toe to top of the end slope, which lies at the natural angle of repose, so that no retaining wall is needed. The construction of such abutments is usually in connection with deck spans, the bridge seats being arranged upon a cross wall at the end of the abutment pier, as shown in the figure—hence the term "T-abutment." High abutment piers of this kind have sometimes been built as narrow as 7 ft. thick, except at the top, which is corbeled out to a width of 12 ft. or more to support and retain the ballast for the track.

The "T" abutment shown in the Fig. 442 is 9 ft. thick, and to replace the three top courses of stone, which had begun to disintegrate after long service, the whole top was remodeled by building a concrete coping to retain the ballast, on plans shown by Fig. 443. In beginning the work the ballast was removed from the top of the old masonry and the track was temporarily supported on timber stringers. The three top courses of the old masonry were then removed and the concrete coping was deposited in sections 6 ft. long. To firmly bind the sections together, two old rails were embedded longitudinally in the concrete, as shown. The top of the concrete coping is finished out to retain 18 ins. of ballast under the bottoms of the ties. To afford drainage the concrete bed is crowned 3 ins. in the center, and 4-in. tile drains projecting one inch from the face of the masonry serve to carry away the water collected. The concrete coping protects the body of the pier against further injury from seepage, and the corbeling of concrete protects the face of the masonry from dripping water. This style of coping has also been applied on this road to new "T" abutments built of concrete from the bottom up, to take the place of trestle approaches to some of the bridges rebuilt.

As bearing upon some of the questions hitherto discussed, reference may be made to the recommendations of a committee report to the Association of Railway Superintendents of Bridges and Buildings in 1897, as follows: "(1) Ties 12 ft. long, spaced 6 ins. apart in the clear, supported directly under the rails and near the ends; (2) suitable inside guard rails and spacers at ends of ties; (3) squaring the floor at the ends of skew bridges; (4) connecting bridge floor with approach by the method shown [Engraving *A*, Fig. 435]; (5) making the floor independent for each of the two tracks of a double-track bridge." The last recommendation (5) refers to the use of two sets of ties for the two tracks, the ends of both sets at the dividing line being supported in common upon a single stringer placed midway between the tracks and serving as a side stringer for both sets of ties. The ends of the two sets of ties meeting upon this middle stringer are covered by a single guard timber lag-screwed to the ties of both sets.

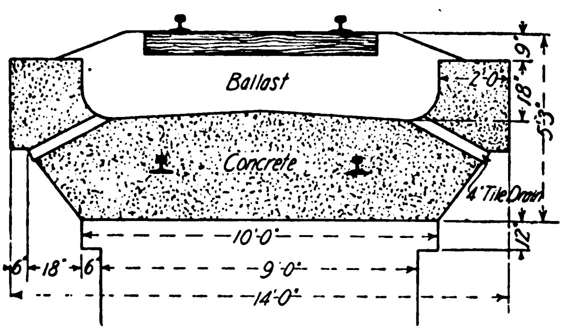


Fig. 443.—Cross Section of "T" Abutment and Concrete Coping, Ill. Cent. R. R.

As the bents of trestle bridges will settle occasionally, the floors of such bridges have to be surfaced to keep the track in smooth condition. Evidently the readiest method of doing such work is to raise and block up the stringers, and on pile bents no other convenient method is available. On the Savannah, Florida & Western Ry. (Atlantic Coast Line) a double cap is used, one over the other. In case of settlement the surfacing is done between these caps. The upper cap is raised by driving a wedge between the two and the shim used runs the length of the cap and is nailed in place. If the bent has settled unevenly at the two sides, however, such method of surfacing will not bring the track back into line. It frequently happens that the slight settling of one side of a trestle bent will throw the track out of line without dropping it much out of surface, especially if the bent be a high one; for it is easily seen that a small settlement at one side of a high bent must throw over the top much faster than the track will settle. If the bent be a framed one the simplest remedy is to jack up the end of the sill at the settled side of the bent and block it to place, when it will usually be found that the track will return to its proper alignment and surface. In the case of uneven settlement in a bridge pier the stringer would have to be moved sidewise, in addition to the work of blocking, in order to bring the track into both line and surface; or, in cases, perhaps, the track could be put in line more easily by pulling the spikes from the rails and respiking them to proper alignment. The most frequent source of trouble in this direction is found with bridge floors supported at the ends upon timber or cribbed foundations, for such are especially subject to settlement. Such settlement is all the more augmented if the end of the bridge comes at a high fill, because the settling of the fill leaves the end of the bridge high; and a train meeting the end of the bridge must be suddenly boosted, as it were, the reaction from which comes upon the end support in the nature of a tremendous blow. This state of things can be helped a good deal by easing off gradually the fall in the track from a point some distance clear of the end of the bridge. Owing to the tendency of track at the ends of bridges to get into rough surface it is a good plan to use 60-ft. rails at such places, so as to remove the first joint on the grade to a good distance from the end of the bridge floor.

Such work as raising stringers at ends of bridges and lining track on bridges is ordinarily done by a bridge gang, but in case the bridge men are slow in getting around the section crew should look to it; and then, whenever the end of the bridge floor is raised, the track for some distance on the fill beyond must generally be raised also, so that the section crew is needed in any event. No slope should be permitted in a bridge floor at the end, to compromise with a settled embankment. The end bent in a pile trestle is sometimes given an extra number of piles—say six, altogether, if the regular number in the other bents is four— in order that it may better withstand the hammering from the trains at this point. The piles in an end bent should, if possible, be long enough to reach down through the embankment and drive to a firm bearing in the solid ground beneath. Where the embankment is new it is sometimes the practice to extend the floor of the trestle temporarily over the embankment one span beyond the end bent and rest it upon mud sills, the extra span to be taken out after settlement has ceased. The wall plate supporting the rails over a masonry abutment is sometimes blocked up at the ends, to give elasticity and cushion the blow due to the sudden transition from earth to masonry support.

Curve Elevation on Bridges.—Where a bridge is located on a curve or on the run-off of a simple curve there arises the question of the method of elevating the outer rail. Among bridge men there is a wide range of opinion on the best method to pursue, owing to which, and to the different styles of bridge floor supports, a number of methods are in service, as follows: (1) By shimming under the outer rail, upon the tie; (2) by the use of tapered or wedge-shaped ties; (3) by shimming or blocking under the ties; (4) by a cushion tie; (5) by raising the outer stringer; (6) by increasing the depth of the outer stringer; (7) by tilting the trestle bent or pair of girders; (8) by inclining the cap.

Shimming under the outer rail is done by spiking a piece of plank to the top of the tie. The shim is placed longitudinally with the tie and is made long enough to carry the guard rail. This method is open to the objection that the track spike loses some of its holding power and the shims are liable to be split or badly cut up by derailed wheels, thus leaving the track in dangerous condition. By this method also the rails do not stand on the same plane and there is an improper inclination of the rails to the wheels, which leads to irregular wear. Wedge-shaped or taper-sawed ties answer quite well for a slight amount of elevation in the outer rail, but an elevation of 4 or 5 ins. requires a very deep stick at one end, thus calling for large timber, which in some localities is scarce. Extra labor is required in sawing the ties, and unless the timber is large enough to furnish two ties in one stick there is considerable waste of material; so that, either from waste of material or from the usual practice of mill men, who, in computing the amount of lumber in the tie, assume the tie to run its whole length at the size of the larger end, tapered ties are much more expensive than common ties. There is also the further objection that in notching the ties for use at the middle portion of a long plate girder, the material which must be cut out to allow for the extra thickness of cover plate must necessarily weaken the tie at the small end and leave it in danger of breaking off in case of derailment. There is also some extra expense attaching to the necessity of having to keep on hand a stock of ties sawed at differing tapers to suit the different bridges on the line.

Elevation of the outer rail by shimming or blocking under the ties may be accomplished in three ways. A tapered block may be used between the tie and the outer girder or stringer, the block being fastened to the tie by bolts or lag screws and the tie dapped over the block and the inner stringer. In dapping the tie over the inner stringer the notch in the tie must be cut to a bevel, owing to the inclination of the tie to the top surface of the stringer, and on a plate girder with a number of cover plates at the center the additional depth of cutting required seriously weakens the tie for service against derailment; and if the grain of the wood does not run with the tie the tie will usually split off at the end, starting from the shoulder of the dap. The most approved method is by the use of two blocks of different thickness under each tie, or one over each girder or stringer. The tie is dapped over the blocks an inch or half inch and the blocks are dapped over the stringers or girders, so that any extra cutting, to allow for extra heavy cover plates at the middle of the span, is made in the blocks and not in the ties. The method of shimming under the ties is done by building upon the outer girder or stringer by laying a longitudinal timber or plank.

A cushion tie is in reality a long, tapering shim extending under both rails. It is made the same width as the tie, or preferably an inch wider, so as to project a half inch over the tie on each side and prevent water from getting between the two. It is about 3 ins. thick at the smaller end and is secured to the tie by means of bolts or lag screws. The objections against the cushion tie are that, being thin at the small end, it is easily warped out of shape by the sun or split by the spikes; and, as usually made, the horizontal joint between it and the tie holds water which rapidly rots out both the tie and its cushion covering. The shallow cushion piece is also somewhat insecure against being torn out by derailed wheels.

The elevation of the outer rail by raising the outer stringer may be accomplished either by a cushion cap or blocking, or by corbeling the stringer. A cushion cap is a stick of timber tapered to the desired inclination of the rails and drift-bolted to the top of the main cap, under the stringers. In order to hold the stringers in line the cushion cap is dapped under the stringers. The principal objections to this method are that the dap under the stringer, and the joint between the cushion cap and main cap will hold water to rapidly rot out the timber; and the stringers do not stand vertically on edge. A similar method that is in practice to some extent is to use a tapering block under the outer stringer and then adz down the top of the cap to an inclination in the same plane, for the inner stringer. Another method, that is seldom if ever employed, is to lower the inner stringer by notching the cap. On the Savannah, Florida & Western Ry., where a double cap is used, elevation is obtained by placing blocks between the two caps. The use of a corbel under the outer stringer gives results similar to the use of blocking under the tie and seems to find favor. Where the corbel method is standard it is generally used under both inner and outer stringers, the outer one being enough thicker than the inner one to give the proper inclination for the ties. Wherever side or jack stringers are in use it would seem that the most desirable way to obtain the elevation would be by some method having to do with the support for the stringers, so that the tops of all the stringers could be placed in the same plane. The elevation may be built in the stringers or girders by increasing the depth of the outer stringer or girder. The objection to this method is that the ties must be dapped at a bevel, and in case of girders having several cover plates in the middle of the span, the increased amount of dapping made necessary cuts deeply into the tie and seriously weakens it for withstanding derailment.

The next method to be considered consists in tilting the trestle bents or the pair of stringers or girders supporting the ties. A trestle bent may be tilted by raising and blocking the end of the sill. This tilting of the bent inclines the cap and gives inclination to the track. The objection to this method is that the middle or "track" posts (which otherwise would be plumb posts) are inclined, and with slowly-moving trains, which do not develop much centrifugal force, the load does not act through the axis of the trestle, with the result that an undue proportion of the load is thrown upon the posts under the inner rail, with three of the posts acting as batter posts and leaning toward the inside of the curve, with only the inside post to oppose this action, and that with its batter reduced. As a result the bracing must stand a heavy racking stress. The seriousness of the latter objection disappears to some extent where the middle posts of the bent are set at a batter instead of vertical. The same objections apply to a leaning bent on a horizontal sill; that is, a bent built by framing the outer posts longer but with the axis of the system of posts inclined. The method of obtaining elevation in the outer rail by tilting up the pair of stringers or girders under the rails, by blocking under the outer girder, is objectionable from the fact that at slow speed the load acts vertically on the tilted girder, thus introducing a sidewise component for which the girder was not designed.

The last mentioned arrangement (8) for obtaining curve elevation on trestles, namely by inclining the cap, is much in favor and is extensively practiced. In applying this method to framed bents the sill is laid horizontal and the posts stand in the usual manner, the cap being inclined by lengthening the posts on the outer side. If the bent is more than one deck high, only the top deck or top story is framed with an inclined cap. In pile bents the piles are cut off at the proper hight to receive the cap at the desired inclination, the cap being sometimes framed on to the piles and sometimes dapped over and drift-bolted to them. It is to be noticed that by this method of inclining the track the elevation of the curve cannot be changed without resorting to one of the other methods above mentioned.

The stringers for supporting curved track on bridges or trestles are sometimes sprung to the curve. In one instance which might be cited as an example, a five-deck trestle 77 ft. high was located on a 6-deg. curve. The length of span was 15 ft. c. to c. of bents, and the stringers, three in number for each side of the track, were 8x16 ins. in size and 30 ft. long, laid to break joints over the caps and sprung to the curve. To strengthen a curved trestle against heavy stresses from centrifugal force the bents should be securely cross braced.

Bridge Guard Rails.—A question of first importance in the design of a bridge floor is the arrangement of the guard rails. If a derailed truck gets badly slewed on a bridge there is much danger of a serious wreck, both of the train and the bridge, especially a through bridge or one on which the trains run between the trusses. It is highly desirable, then, that means be provided to restrain the derailed wheels and keep the truck as nearly parallel with the track as is possible while passing over the bridge floor. The proper position for bridge guard rails is inside the track and not outside, for this reason: When all the wheels of a truck leave the rails and swing askew to the track, the wheels on the front axle almost always take the lead in guiding the truck, and of these two wheels the one running in the track takes the advance. If inside guard rails be in use the wheel which must run against the guard rail is the one in the advance; moreover, the side of the wheel which brings up against the guard rail is the inside, the portion of the wheel in contact with the guard rail being the guard side of the flange. On the other hand, if the guard rails are placed outside the track there is no guard rail in position for the leading wheel to meet, and its mate, the lagging wheel, which is outside the track, brings up against the guard rail. It is then to be noticed that with outside guard rails the portion of the wheel which comes in contact with the guard rail when the truck is slewed is the outside of the wheel or the corner of the tread. Now it must be clear that any obstruction to the leading wheel has a tendency to swing the truck in line with the track; but if the lagging wheel meets with obstruction the action is directly the reverse, the tendency being to slew the truck all the more. An inside guard rail retards the leading wheel of the front axle, which makes contact by a rounded edge (back side of the flange), so that the tendency of the wheel is to sheer off; moreover, the wheel is guarded the full depth of the rail. An outside guard rail retards the lagging wheel of the front pair, which, meeting the guard rail with the sharp corner of the tread, has a tendency to cut in and climb over; and all the more so because the wheel, being lifted to a hight equal to the depth of the flange (or the tendency being such), cannot be guarded so deeply. The action with inside guard rails is therefore to assist the derailed truck to swing back parallel with the track, whereas the effect of outside guard rails is to do the reverse.

The guard which meets all requirements most satisfactorily is an ordinary rail placed inside each running rail, about 8 ins. in the clear. The usual arrangement is to spike such guard rails to the ties (alternate ties) in the ordinary manner, and when such is the case the rails should be spliced on the service side with fish plates, putting the bolts through from the service side, so that the nuts cannot interfere with, or be reached by, the wheels in case of derailment. Old rails worn out in service are as good as any for this purpose, but a rail should not be used which presents a slivered or ragged head to the service side, because derailed wheels are liable to bite into the roughened edge and mount the rail. Preferably the guard rails should be the same hight as the running rails, but rails of ordinary section, even if not quite as high as the main rails, are satisfactory. In order to present a smooth service side, without spikes or bolt heads to interfere with derailed wheels, it is the practice on some roads to splice the rails together and turn them on side, using the flange of the rail as the service side of the guard. One method of holding the guard rail in this position is to bolt it to cast iron chairs, which in turn are bolted to the ties. On the Elgin, Joliet & Eastern Ry. the guard rails are turned on side and laid directly upon the ties, being fastened by bolts passing through the web of the rail and the tie.

As a wheel will readily bite into and mount a low timber there is not room to put effective timber guards inside the rails, unless the timber has metal protection on the service side. Such protection is sometimes afforded by facing the service side of the timber with a flat bar of iron laid with the top edge flush with the upper corner of the timber. A better arrangement is to face the service corner of the timber with an angle iron. Angle irons are sometimes used for inside guards in lieu of rails, the horizontal leg of the angle extending inward, toward the middle of the track, and bolted to the ties. In some cases the vertical leg of the angle is backed by a timber laid on flat over the horizontal leg and bolted to the ties through the portion which overlaps the horizontal leg. In other cases the horizontal leg of the angle is turned toward the running rail, as in Fig. 437, so as to form the bottom of a channel for the derailed wheels, the angle then being bolted to the timber backing through the vertical leg. Inside guard rails are all the better if they extend as high as the running rails, but they should not extend higher. A suitable size of timber for an inside guard would then be 5 x 8 or 6 x 8 ins., the stick laid on flat and dapped over the ties. The floor of the Boone viaduct, on the Chicago & Northwestern Ry. (Fig. 437), consists of yellow pine ties 12 ft. long and 8 ins. square in section, laid directly upon the plate girders and spaced 12 ins. c. to c. On each side of each rail there is spiked a 4x10-in. plank, those in the track being faced on the service side with a 6x4½-in. angle iron. At the ends of the ties there is a 10x12-in. yellow pine timber guard laid on edge and bolted to the ties. On the outside of the bridge these timbers are broken at the hand-car refuge platforms, so that they do not appear in the figure. On roads where snow plows are used timber guards that are much higher than the rail cannot, for obvious reasons, be laid near the latter. Where such conditions exist it is therefore possible to hold derailed wheels nearer to the running rails with inside guard rails than with outside ones.

In general practice inside guard rails are extended from 60 to 150 ft. beyond the end of the bridge and gradually deflected to meet in the middle of the track. The ends of the rails are usually made to abut against a terminal or point piece, which sometimes consists of a cast block running to a point, and sometimes an old frog point is spliced to the guard rails. To prevent anything from catching upon the terminal piece the point is beveled down or turned down into the ballast between two ties. On the Lake Shore & Michigan Southern Ry. the two rails run together and turn down into the ballast between two ties, being bolted together at the ends through a cast filler block. If the approach to the bridge be on a curve the safest plan is to extend the guard rails all the way around it before bringing them to a point; or to run them to a point, say 60 ft. ahead of the bridge, and then lay a single rail in the middle of the track the rest of the way around the curve. The purpose of deflecting the guard rails to the middle of the track is, of course, to catch derailed wheels and gradually guide them close to the running rails, and into line with the track. In order that the guard rail may have sufficient support or backing to properly perform its function, the inside of the rail throughout its curved portion should be well braced. Concerning the efficacy of this arrangement for general service there is some difference of opinion. In almost all cases where the derailed wheels are not far from the running rails the arrangement accomplishes its purpose, although one occasionally hears of an instance where the wheels refuse to be constrained and jump over the guard rail. Such is quite likely to be the case where the derailed wheels on one side are running off the ties, as it would be easier for the wheels on the ties to mount the guard rail than it would be for the guard rail to draw the other wheels back onto the ties. One can readily understand how such a result might obtain where the ballast is not filled in against the ends of the ties. For this reason it would seem that the use of a set of long ties, or switch ties, extending the length of the deflection in the guard rails would be an important aid in bringing derailed wheels into position to travel safely over the bridge, and a third guard rail, laid in the middle of the track, might come into play in any case where the wheel jumps over the deflected guard rail.

In remote cases derailed wheels are diverted by more than half the track gage, and then the deflection of the inside guard rails works a result exactly the opposite of that intended, for if the inside wheels catch the guard rails past the center of the track the truck will be thrown still farther away, and cases of this kind are on record where the car has been thrown into the end post of the bridge, knocking it down and wrecking the bridge. To avoid such consequences it has been proposed that snubbing posts in the form of a cluster of piles be erected in advance of and in line with the bridge post, to break up any cars which are so badly out of line as to strike the bridge post, and thus wreck the train before the bridge is reached. At a number of through bridges on the Grand Trunk Ry. there is a wall of cut stone masonry about 3 ft. thick, 6 ft. high and 30 ft. long, in front of and in line with each truss to protect it from injury by derailed cars. Another plan in practice is the use of a pair of flared guard rails placed outside the running rails just in advance of the guard point, so as to catch the truck and deflect it into position to take the right side of the inside guard rails. These outside advance guard rails are laid upon switch ties and braced, the leaving ends (opposite the guard point) being about 8 ins. clear of the running rails, and then flaring to a distance of about 5 ft. from the running rails at the entering end. Engraving *E,* Fig. 444, shows the arrangement, except that timbers are used for guard pieces instead of rails. The device illustrated is known as the Childe-Latimer bridge guard. The guard timbers flare out to a distance of 7 ft. from the center of the track or to a distance apart which corresponds to the distance between the bridge trusses. The large posts set in the ground to back up the ends of the flaring timbers are 16x16 ins., 12 ft. long, the top standing 4 ft. above top of rail. When timbers are used for these flaring guard pieces the upper corner on the service side of each should be sheathed with an angle iron to prevent derailed wheels from biting into it. These timbers should not be smaller than 10x10 or 12x12 ins. From the leaving end of the advance guards there should be outside guard rails parallel with the running rails, extending toward the bridge, to prevent the wheels from dropping off the ties until they reach a point where the deflected inside guards come close enough to the running rails to hold them on.

The fact that derailed wheels will sometimes take the wrong side of guard rails deflected to the center of the track has induced some to abandon the practice of deflecting the rails at all, but to lay them parallel with the running rails their whole length. Such is the practice on the Michigan Central R. R., and in addition a third inside guard rail is laid in the middle of the track. Each guard rail is turned down into the ballast, at each end, so as not to catch anything loose hanging from the cars. The idea which here obtains is that the safest plan is not to attempt to change the position of the derailed truck from that in which it first strikes the guard rails, and that any arrangement which will prevent it from swinging into a worse position while crossing the bridge is a sufficient protection. The middle guard rail serves to keep the inside wheels from getting past the middle of the track while on the bridge, but if they are already past the middle of the track before it reaches the bridge the guard rails do not operate to make the condition of things worse, as is sometimes the case where the guard rails are deflected to the middle of the track, as above explained. It may be well to remark that on through bridges with trusses standing widely apart this principle is undoubtedly the safest to follow out in practice; but on narrow bridges the advantage is with the two-line pointed guard, for if the derailed wheels have passed the center line of the track the car would strike a truss in any case, as also it might with the three-line guard if the wheels have nearly, if not quite, reached the center line; but in that case two-lines of guard rails converging to the center might draw the derailed car out of reach of the truss. On deck bridges the advantage would seem to lie with the three-line guard, without question, and a peculiar advantage in any case is that the three lines of rails may serve to carry badly slewed wheels, broken trucks, sliding car bodies, etc., clear of the ties, with less liability of bunching the latter than would be the case where the middle of the track is open.

The three-line straight bridge guard in use on the Michigan Central R. R. was designed by Mr. O. F. Jordan, formerly roadmaster with that road, and is known by his name. It consists of three lines of rails equally spaced between the main rails and parallel to the same throughout. The turned-down ends are inserted through a ½-in. iron or steel plate covering the space between the main rails and spiked to the ties. As first constructed, there was a rail on the under side of the ties (making four rails in all) bolted through and through with the middle guard rail, but this under rail is no longer used. Some other roads which use the Jordan bridge guard are the Lake Erie & Detroit River Ry., and the Toronto, Hamilton & Buffalo Ry. At one time the Chicago, Milwaukee & St. Paul Ry. used a bridge guard designed on a similar principle. It consisted of two T-rails, laid 10 ins. inside the main rails, and a 5x6-in. oak timber laid on flat in the middle of the track and dapped over the ties 1 in. The top of this timber was capped with a 6-in. channel iron inverted and bolted through and through at every fourth tie. The center guard ended at the ends of the bridge and was beveled down to prevent anything dragging under a train from catching, but the rail guards extended 150 ft. beyond the ends of the bridge. Besides the three guards in the track there were the usual timber guards near the ends of the ties. In course of time the use of the center timber guard was abandoned. A noteworthy feature of bridge floor design that is standard with this road, as touching the subject now in view, is to have no bolt heads or other projections where they will catch derailed wheels or parts of a car or its running gear that may be dragging.

It is quite commonly the practice to dispense with guard rails inside the track and depend upon guard timbers outside the rails. When such is the case the guards should be placed close enough to the rail—say 8 or 10 ins. from the rail in the clear—to serve as well as possible the purpose of a guard rail and prevent derailed trucks from becoming badly slewed in the track. If ties as long as 12 ft. are used the timber guard dapped over the ties near their ends, to keep them from bunching, is not close enough to the rail to be of service in holding derailed wheels on the floor, since the truck is already slewed so badly by the time the wheel strikes the guard timber that it cannot be turned back into line with the track, and consequently trouble is likely to ensue. Hence, if guard timbers are to be depended upon to hold the wheels on the floor they should be placed close to the rails, and beyond the ends of the bridge the timbers should be gradually flared out a sufficient distance from the rail to catch badly derailed trucks and deflect them into line with the track. These flaring guard ends should be laid upon switch ties placed in the track on the approach to the bridge floor. Owing to the tendency of derailed wheels to bite into timber, a low timber guard outside the rails, without inside guard rails, becomes an element of danger and actually worse than no guard at all in case of derailment, because of its action in retarding the wrong corner of the derailed truck and the liability of the wheel to mount it. For this reason the upper corner on the service side of the guard timber should be faced with an angle iron. If such protection is not provided the timber guard should never be less than 8 ins. high above the ties, but it is best to provide the metal protection for timber of any size. On some bridges of the Boston & Albany R. R. 10x12-in. hard pine guard timbers set $2\frac{1}{2}$ ft. from the rails are used, without inside guard rails. At the end of the bridge there is a flared approach consisting of rails laid to turn derailed wheels inside the line of guard timbers. The bridge guard of the Grand Trunk Ry. consists of a T-rail laid outside each main rail, at a distance of 12 or 15 ins., and well flared out beyond the ends of the bridge. Guard timbers should be securely bolted to every third or fourth tie, but if they are not dapped over the ties they should be bolted to every tie. If inside guard rails are used the outside guard timber is not needed, and it should then be placed so far from the rail that derailed wheels cannot reach it so long as they are held by the inside guard rails. At this distance from the rail it can perform its true function equally well, which is to keep the ties properly spaced and prevent them from spreading and bunching in event of a derailment. A piece of timber of square cross section is preferable to an oblong section for guard rails, owing to the fact that a choice of four sides is had for either the line side or the upper face of the timber.

In connection with inside guard rails a replacing device is sometimes used. The arrangement consists in laying the guard rails close inside the running rails and placing an inclined plane or "elevating casting" each side of each running rail at the point where the flared opening at the heel of the deflected portion of the guard rails draws to a close. The inclined planes are cast blocks, similar to the filler blocks of a frog, and each running rail with its guard rail and the incline castings are bolted together through and through, like a bolted frog. The incline castings gradually bring the wheels up to a hight even with top of rail, where they are constrained by the guard to take the rails again. One of the best known rerailing devices is the Latimer bridge guard, shown as Engraving *D*, Fig. 444. The Childe-Latimer bridge guard, shown as Engraving *E*, is a later improvement. In addition to the rerailing device and inside guard rails deflected to a point piece in the middle of the track there are outside flare guards in advance of the guard point, to steer derailed wheels to the right side of the guard point, as already explained.

While some claim much for a rerailing device at the end of a bridge others think that it may not be needed, and in cases may actually make matters all the worse for the derailed truck. Thus, for instance, it is claimed that a set of wheels which can be brought over by the guard rail and held until they reach the replacer will, in all probability, cross the bridge in safety, because the guard rail must do its important work before the replacer is reached; i. e., it must get the truck swung pretty well in line with the track. Now many think that when this much has been accomplished the chances of further trouble on the bridge are so slight that it would not be advisable to attempt to better the situation by taking further risk; for it must be admitted that to attempt to replace wheels on the rails at high speed with any form of rerailing device is doing it at the hazard of jumping the truck into a worse position than it had before. At high speed the truck would necessarily be swung with considerable momentum; and when the wheels have been raised out of the rut between the running rail and guard rail, it is difficult to tell how far the truck might swing. It does look a little like a case of not "leaving good enough alone." Such replacing devices when used should not be on the bridge, as the shock which might come upon the structure should the device fail to replace the wheels on the rails might cause dangerous stresses. It would be better to place it two or three rail lengths in advance of the bridge.

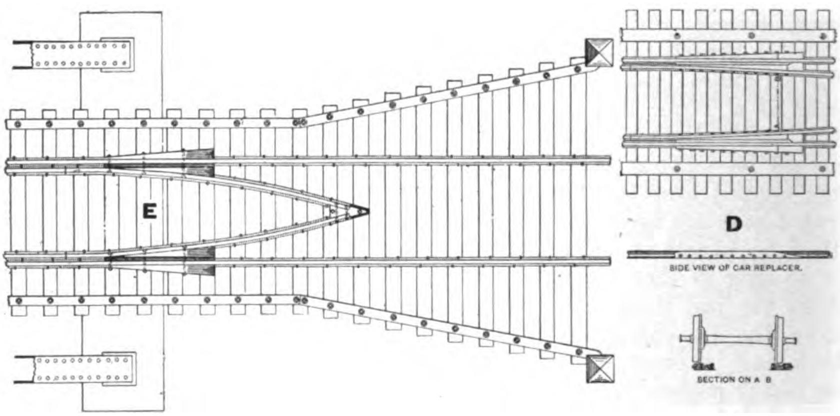


Fig. 444.—Latimer (D) and Childe-Latimer (E) Bridge Guards.

Wherever the supports of an overhead structure stand at the side of a track, as at crossings on separated grades, they should be protected against dislodgment by derailed cars. This may be done by laying guard rails in the track as on a bridge floor. Such guard rails are usually run to a point in the middle of the track, 50 or 100 ft. in advance of the columns or other supports, after the ordinary manner with bridge floor guards, but if the supports to be protected stand on only one side of the track, only one guard rail is usually laid, that being, of course, near the rail that is on the opposite side of the track from the object to be protected. In addition to the guard rail protection it is customary to build a masonry pier parallel to the track to surround the supporting columns to a hight of 4 ft. or more. Such piers or walls usually perform no service in supporting the overhead structure, being placed simply to encompass the column supports and fill intervening space in a manner to guard the supporting columns against shock or displacement by derailed cars. In some of the track elevation subways in Chicago concrete protection walls are built around the columns supporting the overhead bridges. An example of such construction on the Chicago & Western Indiana R. R. is illustrated in Fig. 445. The foundation for the wall is 4 ft. 4½ ins. wide and 14 ins. deep, extending to a level 2 ins. below that of top of tie. The wall built thereon is 3½ ft. thick at the base, tapering to a thickness of 1 ft. 9 ins. at a hight of 4 ft. 1½ ins. above the base, above which the wall has a uniform thickness of 1 ft. 9 ins. The hight of the wall above the foundation is 10 ft. The ends of the wall are prow-shaped, the top receding 7 ft. from the bottom, on the extreme edge, which is 6 ins. wide. Some of the protection walls in this subway are 243 ft. long and are provided with arched retreats through the wall at four different places, the opening being 3 ft. wide and 5½ ft. high.

Fire Protection.—As wooden bridges are liable to take fire from passing trains or from fires which spread over the right of way, the question of providing means for fighting such fires, or for protecting the structure against taking fire from trains, readily suggests itself. At wooden bridges or trestles it is customary to place barrels of water for service in case of fire, and at iron bridges at least one barrel is needed to protect the bridge floor. The barrels at the ends of bridges are usually sunk into the embankment, to insure that they will not be tipped over by mischievous persons. To prevent freezing during winter the water is salted. Where the weather becomes only moderately cold two buckets of salt to each barrel is sufficient, but in some parts of the Northwest where extremely cold weather is prolonged, one third to a half barrel of

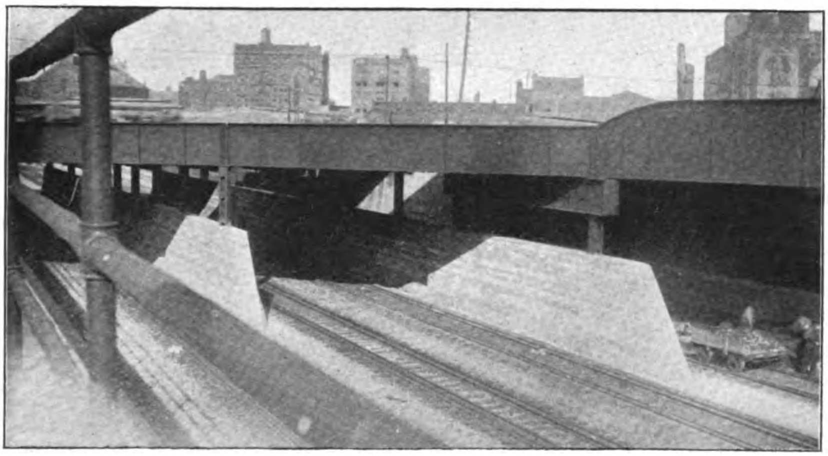


Fig. 445.—Concrete Protection Walls, for Bridge Supports, C. & W. I. R. R.

salt is used to each barrel of water, and even then the water on top will sometimes freeze into slush. On some roads a stick of wood is stood upright in the center of the barrel, projecting a few inches above the top, to prevent the barrel from bursting in case the water freezes into ice, but plenty of salt will usually keep the water in condition for use. In practice it is found to be necessary to renew the salt every fall, and, as might be expected, the use of salt requires frequent renewing of the iron hoops on the barrels. The barrels should be provided with heavy covers chained to the side, and a water bucket should be sunk in each barrel for use in case of fire. Whenever water is added to the barrels the condition of these buckets should be examined, for a coal oil can or tin pail with the bottom eaten out with rust or a wooden bucket with the hoops eaten off is a poor weapon for fighting fire. On long bridges or trestles it is customary to have water barrels stationed at frequent intervals, usually on the trestle caps or on a platform extending beyond the ends of the ties. The section men are required to keep these barrels filled, so that they will not be checked by the sun and become leaky. At bridges where water is not handy the water barrels, if numerous, should be filled periodically by hose from a tank car or from the tender of the work train, as the cost of trucking water by the section crew is too great.

Concerning systems of watching wooden bridges against fire there is no generally uniform practice. On some roads no regular bridge watchmen are employed and, aside from the chance that the section crews may pass over the bridges once or twice a day, they receive no particular attention. In other cases watchmen are employed during the dry season of the year to pass over each bridge after the passage of a train, keeping close watch for fire. In case there are a number of wooden bridges within a distance of a few miles the watchman is given a velocipede hand car and is required to look after all of the bridges within the limits of the beat he is able to ride over between trains, within a reasonable time after the passage of the trains. In watching bridges the watchman should not pass the bridge sooner than 15 minutes after the passage of a train, since fire starting from sparks might smolder or not get sufficiently

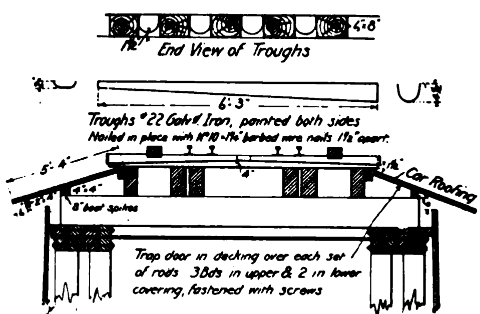


Fig. 446.—Covering for Howe Truss Deck Bridges, C., M. & St .P. Ry.

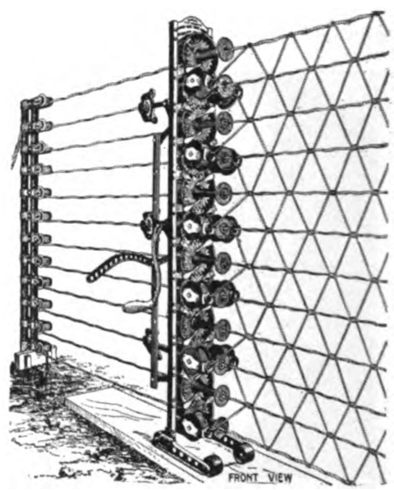


Fig. 446A—Kitselman Woven Wire Fence Machine.

started to attract notice until after a few minutes from the time it begins. In other cases important wooden bridges, particularly long ones, are placed in charge of a watchman who patrols the bridge after the passage of each train, at all times of the year. Oak bridge ties are not liable to take fire except during extremely dry weather, and even then it is seldom that the fire will spread and burn the tie to the danger point. Nevertheless it is a good plan to have water barrels at all bridges—whether of wood or of iron—if there are wooden ties in an open floor.

It is quite frequently the case that means for protecting wooden bridges from fire are provided in the construction of the bridge floor. One method is to cover the ties with galvanized sheet iron, making a close fit with the rails by upturning the edges of the sheets. Another method quite extensively in use on wooden trestle bridges is to cover the stringers and caps with galvanized sheet iron. Such protection keeps the fire from the vital parts of the floor and protects the parts covered, even though fire may burn some of the ties. On the Louisville & Nashville R. R. the galvanized iron used is No. 20 Birmingham gage and is put on the caps in strips 25 ins. wide and 7 ft. 9 ins. long. The strips overlap 6 ins. and are riveted together with flat-head, soft iron, tinned rivets $^5/_{16}$ in. in diameter and $\frac{3}{8}$ in. long, placed in the center of the lap, $2\frac{1}{2}$ ins.

apart. Each set of stringers is made up of three 7x14-in. pieces and is covered with strips of galvanized iron 33 ins. wide. In either case the iron is turned down 5 ins. over each edge of the timber, at an angle of 45 deg., so that anything which falls upon the stringers or caps, when it slides off, will fall clear of the trestle bent. Such a covering also protects the timber from the weather and is sometimes applied to the upper chord pieces of wooden trusses. The Southern Pacific wooden deck truss shown as Engraving *B,* Fig. 434, is so protected. The top of the top chord, under the floor beams, is covered with No. 24 galvanized iron turned down 3 ins. over the edge of the timber and tacked.

In the case of a wooden truss deck bridge adequate protection from fire cannot be had without covering the structure. One method in practice on some of the southern roads is to fit planks between the ties, forming troughs, and then to close the ends of the troughs by fitting pieces of boards between the ties. The space between the ties, and for a depth of about an inch over the tops of the ties, is then filled with gravel or sand. Gravel is said to answer the purpose best, because it does not wash out through the cracks between the tie and the plank. The use of gravel or sand has the effect of rotting out the ties much sooner than would be the case with ties in an open floor. On the Boston & Maine R. R. wooden deck trusses are tightly roofed over with two layers of ⅞-in. boards laid at a pitch of 1 in. to the foot, as shown by Engraving *A,* Fig. 434. The floor beams are laid directly upon the top chord and, being spaced only 2 ft. 7½ ins. centers, heavy stringers are not needed. The roof boards are butted at the ridge and covered with a strip of galvanized iron 18 ins. wide. The ties are "saddled" or cut out on the under side so as to fit over the peak of the roof. The tie remains 4 ins. thick in the middle, which is supported by a ridge stringer 6x12 ins. in section. The roof boards are painted and sanded as a protection against fire. By another method, in service on the Philadelphia & Reading Ry., the ties or the stringers are not disturbed. The stringers are covered with sheet metal, which is turned down over the edge of the piece, and roof boards are butted against the stringer, near its upper corners, so that the sheet metal covering laps the joint. Outside the stringers the roof boards slope beyond the floor beams and between the stringers the roof boards form a valley. A covering for Howe truss deck bridges that is used on the Chicago, Milwaukee & St. Paul Ry. consists of roof boards outside the stringers and galvanized sheet iron troughs between the ties. The details are explained by the legends in Fig. 446.

Of late years considerable attention has been given to the question of protecting iron bridges from corrosion by the brine which drips from refrigerator cars. The increasing amount of traffic in such cars has enforced upon bridge men a problem requiring serious study, and the only solution seems to lie in completely covering the bridge. On the Cleveland, Cincinnati, Chicago & St. Louis Ry. the stringers and chord pieces of iron deck bridges are protected from brine by painted beveled blocks, fitted closely between the ties, so as to cover the parts exposed.

Bridge Floors Over Streets.—The elevation of tracks over streets in cities has developed a number of special designs for solid bridge floors. The conditions imposed usually require that the bridge floor shall be tight, to prevent anything dropping from the cars into the street, and the desire to reduce to the lowest practicable limit the hight of the embankment filling, considered in connection with the headway requirements, calls for a shallow floor. The track in such cases is usually carried by through plate girders, and a very common type of floor is had by using I-beams for floor beams, between the girders, resting them either directly upon the lower flange of the girder, or upon hangers attached to the web plate; then covering the I-beams with floor plates or with longitudinal rail plates, to which the rail is secured by means of bolts and clips. The guard rails usually consist of angle irons riveted to place and the floor plate is tarred and graveled, so as to shed water. The Chicago, Burlington & Quincy Ry. floor for street viaducts is formed upon 15-in. I-beams spaced $14^{11}/_{32}$ ins. apart from center to center, and resting directly upon the lower flange of plate girders spaced 13 ft. apart. The I-beams are covered with a $^5/_{16}$-in. floor plate and the rails are secured by bolts and clips to longitudinal rail plates 20 ins. wide and $\frac{1}{2}$ in. thick riveted directly to the I-beams. A $5 \times 3\frac{1}{2} \times \frac{1}{2}$-in. angle iron is riveted to the rail plate, 9 ins. clear of the rail, on either side, to serve as a guard

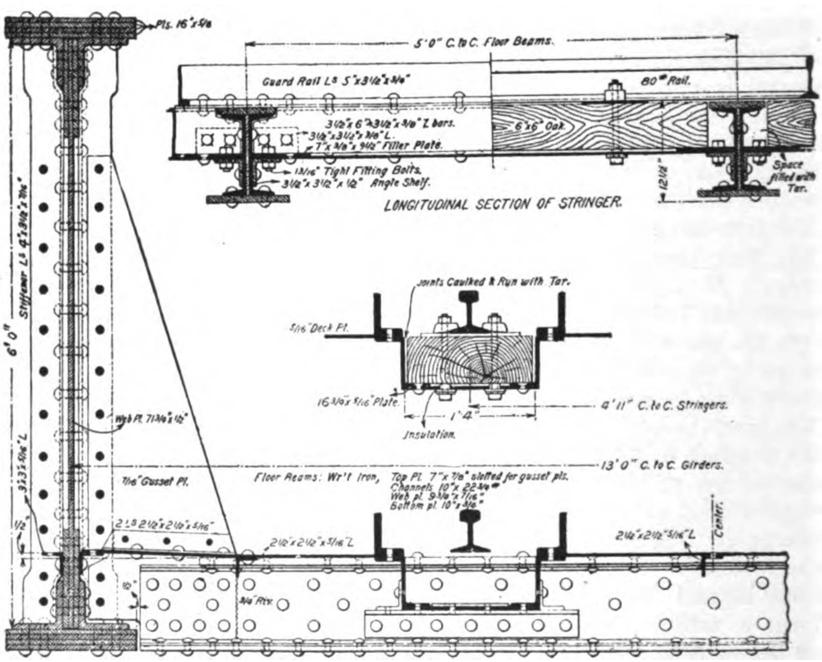


Fig. 447.—Floor for Street Viaduct, Chicago & Northwestern Ry.

rail. The floor of street viaducts on the St. Charles Air Line is made of 12-in. I-beams spaced 12 ins. centers, and covered with a $\frac{3}{8}$-in. plate. The rails are carried on special short plates laid on the floor plate, and a Z-bar is riveted to the floor plate, each side of each rail, to serve as a guard rail. The plates under the rails vary in thickness from $\frac{1}{8}$ in. at the center of span to $\frac{1}{2}$ in. at the end of the bridge, half of the camber being taken out by these plates. The floor plate is not laid directly upon the I-beams but upon filler plates or strips 3 to 5 ins. wide, varying from a thickness of $\frac{5}{8}$ in. in the middle of the track to $\frac{3}{8}$ in. under the rails and nothing at the plate girder, so that the floor has a transverse slope each way from the middle of the track and a longitudinal slope each way from the middle of the span. The floor beams (12-in. I-beams) are attached to the web plate by hangers and are suspended above and just clear of the lower flange of the girder.

The standard floor for street viaducts on the Chicago, Rock Island & Pacific Ry. has 12-in. I-beams attached to oblique hangers, so that the bottom of the beam is even with the bottom of the girder. The hanger plate is 9 ins. wide and $\frac{1}{2}$ in. thick and stands at an angle of 45 deg., being bracketed against the web plate and across the edge of the lower flange of the girder. The I-beams are spaced $13^7/_{16}$ ins. center to center and covered with a $^5/_{16}$-in. floor plate. Longitudinal rail plates $\frac{3}{4}$ in. thick are laid upon the floor plate, to which the rail is secured by bolts and clips, the bolts reaching through the floor plate. A 6x4x$\frac{1}{2}$-in. angle iron laid on flat and riveted to the rail plate outside each rail, 9 ins. in the clear, serves as a guard rail. The floor plate is tarred and covered with finely crushed screened rock, and then with a layer of gravel about 3 ins. deep, to deaden the sound of trains passing over the bridge. On viaducts over other roads or where the subway does not carry street traffic the floor plate is omitted and the floor remains open, the rail plate in that case coming directly upon the floor beams. The floor system for street viaducts on the Chicago, Milwaukee & St. Paul Ry. is built upon 12-in. 45-lb. I-beams spaced 15 ins. centers. The I-beams rest directly upon the bottom flange of the plate girders and are riveted thereto. On tangent the plate girders are spaced 13 ft. centers. The I-beams are covered with a $^5/_{16}$-in. floor plate and the rails are carried in 10-in. channels laid upon the floor plate. The bearing for the rail is a cushion of oak timber $1\frac{5}{8}$ ins. thick, laid in the channel and covered with a $\frac{1}{4}$-in. steel plate upon which the rail bears directly. The rail is secured by $\frac{7}{8}$-in. U-bolts and clips at intervals of 30 ins., the legs of the U-bolt extending through floor plate, channel, the oak cushion and its cover plate. The U-bolt straddles a cast saddle block bearing against the under side of the floor plate. On curves the superelevation of the outer rail is obtained by increasing the thickness of the cushion timber in the channel. The application of a coating of asphalt composition to the floor plate of these bridges, to protect it against corrosion from salt water drippings from refrigerator cars, did not prove a successful experiment The difficulty with the asphalt was that it cracked and peeled off, leaving the metal unprotected.

The standard floor for street viaducts on the Chicago & Northwestern Ry. is shown in Fig. 447. The floor beams are built of two 10-in. channels spaced $\frac{1}{2}$ in. apart, with top and bottom plates. The floor beams are spaced 5 ft. apart and are connected with the girder by gusset plates which project 2 ft. and go between the channels of the floor beams. There is a filling piece between the channels, extending from gusset to gusset, thus giving a thick web. The bottom of the floor beam comes even with the bottom of, and stands entirely clear of, the lower flange of the plate girder; and, being riveted to the gusset plate, the load is carried directly to the web plate of the girder. The track stringers are made of two Z-bars riveted to a $16\frac{3}{4}$x$^5/_{16}$-in. plate, forming a channel, into which is fitted an oak block 16 ins. wide and 6 to 7 ins. thick, forming a cushion for the rail, the arrangement being similar to the Chicago, Milwaukee & St. Paul device, above described, except that in the latter case the channel rests upon the top of the floor beam instead of butting against it as in this case. There is a camber of one inch in the girders, for drainage, and the variation in the thickness of the block levels the rail. A 5-in. angle iron is riveted to the top of the Z-bar channel, on each side of the rail, to strengthen the channel and to act as a guard rail. The cushion block is covered with a rail plate and the rail is secured by clips and bolts, the latter reaching through cushion block and bottom plate, as shown. The rail is carried just clear of the floor beams. The floor beams are covered with a $^5/_{16}$-in. plate, which is stiffened with

$2\frac{1}{2}$x$2\frac{1}{2}$x$^5/_{16}$-in. angles on the under side. The floor plate is then covered with a coat of gravel roofing to protect the metal. The purpose of the cushion block in the bridge floors here mentioned is to deaden the sound of trains passing over the bridge.

In some cases a solid floor is secured by the substitution of buckled plates for I-beams. Thus, some of the bridge floors on the Chicago, Rock Island & Pacific Ry. were built up of plates and angles into a continuous corrugated surface with rectangular troughs running crosswise the track, suspended directly from the web plate of the girders by hangers. The rails are attached by bolts and clips to longitudinal rail plates 18 ins. wide and $\frac{1}{2}$ in. thick resting directly upon the ridges between the troughs. Inside guard rails (T-rails) are secured to the rail plate and a 4x$3\frac{1}{2}$x$\frac{1}{2}$-in. angle iron is laid outside the running rail and secured to the rail plate. The buckled plate floor of the Illinois Central R. R. is shown in Fig. 448. It is formed of channels having a 5x$\frac{3}{4}$-in. base and $4\frac{1}{2}$x$\frac{3}{8}$-in. legs, alter-

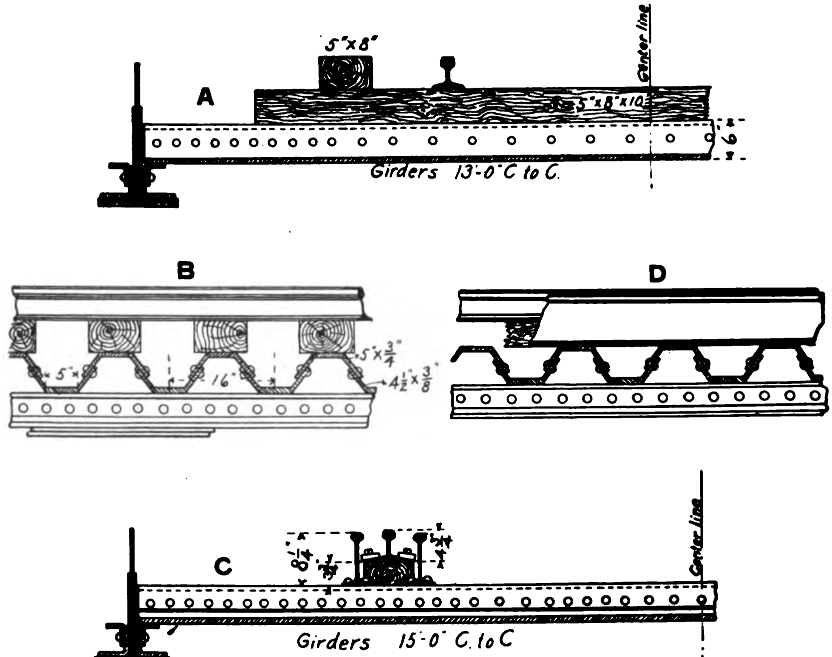


Fig. 448.—Buckled Plate Bridge Floor, Illinois Central R. R.

nately inverted and riveted together, forming a corrugated surface 6 ins. deep. The channels rest upon a shelf angle riveted to the girder over the vertical leg of the bottom flange angle, as shown. The floor for girders spaced 13 ft. centers is shown as Engraving *A*, Engraving *B* being a section of the floor parallel to the track. The ties are 5x8 ins. x 10 ft. long, laid upon the ridges between the troughs, and are held in place by 5x8-in. guard timbers. It was first the practice to place the ties in the troughs, the tie being small enough to fit into the trough and high enough to support the rail just clear of the top of the trough. Later it was intended to raise the tie about $1\frac{1}{2}$ ins. and fill the space around the tie with asphaltic concrete. In order to obtain access to the troughs for cleaning and painting, however, it was finally decided to place the ties on the ridges between the troughs, as shown. Engraving *C* shows the form of floor where the girders are 15 ft. apart and Engraving *D* is a section of this floor parallel to the track. Two 8¼-in. deck beams are riveted to the ridges between the troughs and spaced sufficiently far apart to receive an oak timber cushion for the rail. The cushion is supported by the lower flanges of the deck beams and the rail is secured by bolts and clips. On the Chicago, Madison & Northern line of the Illinois Central R. R. a buckled plate floor is used having troughs 12 ins. deep. The track ties are 6 ins. thick and 10½ ins. wide and are laid in the troughs and supported upon shelf angles placed along the sides of the trough about 7 ins. from the bottom, so that the tie projects 1 in. above the top of the trough. Guard timbers, 10x12 ins. or 12x12 ins., are dapped over the ends of the ties and bolted to them, thus forming a very substantial floor on which the ties cannot be bunched.

Ballasted Bridge Floors.—The most improved type of bridge floor is the ballasted floor, or the "ballasted-top" bridge, as it is sometimes called. The advantages in this type of floor construction are conceded by both bridge engineers and trackmen. From the point of view of the bridge men, the trains pass over the ballasted floor without so much shock to the bridge as is the case when the track is laid upon stringers, owing to the ability of the ballast to take up or receive the vibration from the trains. The weight of the ballast also increases the percentage of dead to live load, thus decreasing the deflection and vibration in the bridge structure proper. From the standpoint of the trackman there is everything in favor of the ballasted floor, both in regard to the question of safety and to facility of maintaining the track in serviceable condition. A derailed truck will travel as safely over such a floor as at any point on the grade; and as continuity of roadbed conditions is preserved over the bridge, the work of maintaining the track in surface and alignment is nowise different from ordinary methods in practice for raising track and throwing it to line upon the roadbed. The ballasted floor is an outgrowth of the long-time practice of covering open culverts with timbers or old rails and filling in over such covering with ballast to support the track, thus doing away with many of the objectionable features of such openings.

The modern improvement in ballasted floors consists of a solid metal covering over the stringers, floor beams, or girders, overlaid with ballast to support the track. The ballasted floor for deck bridges on the Michigan Central R. R. is formed by laying I-beams about 12 ins. apart directly upon the upper chord or upper flange and covering the I-beams with a floor plate. The floor plate is covered with a layer of asphaltum and weep holes are left at intervals for drainage. A curb consisting of a 3½x7-in. angle iron on end is riveted to the side edges of the floor to retain the ballast. The ballast (gravel) is placed upon the asphaltum covering of the floor plate and the track is surfaced in the ordinary manner. On the Chesapeake & Ohio Ry. old rails laid workwise side by side are used for the flooring of plate-girder deck bridges. The rails are spaced 6 ins. apart centers, the rivets in the top flanges of the girders being spaced to come between the rails, the openings being left to drain the water out of the ballast, which is broken stone. On double-track bridges the pieces of rails in the floor are 23 ft. 5 ins. long, extending the whole width of the bridge. The rails are secured to the bridge laterally by an angle iron at their ends which is bolted to a side extension of the top cover plate of each girder. This extension projects out 15 ins. beyond the web plate, and the angle iron against which the rails abut is secured to it with ¾-in. bolts. To retain the ballast and finish up the side of the bridge floor a ⅜x10-in. plate standing edgewise is riveted to each outside angle iron.

More frequently the covering for the ballasted bridge floor consists of buckled plates made by uniting channels, plates, angle bars, or Z-bars in such a manner as to form the corrugated surface. A number of such forms are shown in Fig. 449. Engraving *A* shows diagrammatically a section of floor with troughs having flaring sides, or of trapezoidal section, being formed of channels alternately inverted. This type of construction, known as the "Lindsay" floor, is in use on the Illinois Central R. R., as already noted. Engraving *B* shows the Francis & Dawley floor, in use on the New York, New Haven & Hartford R. R., particularly as a floor for street viaducts in Providence, R. I., and Boston, Mass. The bottom of the trough is formed of channels, the sides of angle bars and the ridge is united by a plate. The advantage of this form of construction is that the cap plate provides a means of spacing the troughs exactly to any desired distance center to center. The depth may also be varied easily by varying the length of the angle leg. Engraving *E* shows a trough of similar shape formed by Z-bars and plates. Engravings *D* and *F* show sections of floors with troughs of rectangular section, the former being composed of plates and angle bars and the latter of channels and plates. If the ties are to be placed in the troughs the top angle bars in *D* and the top channels in *F* should be placed inside the vertical plates of the ridges, but where ballast is to be used the arrangement is best as

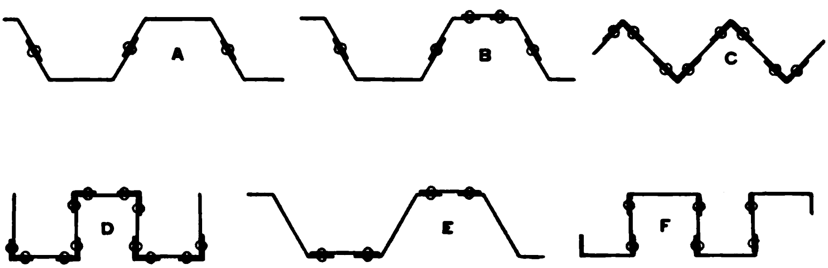


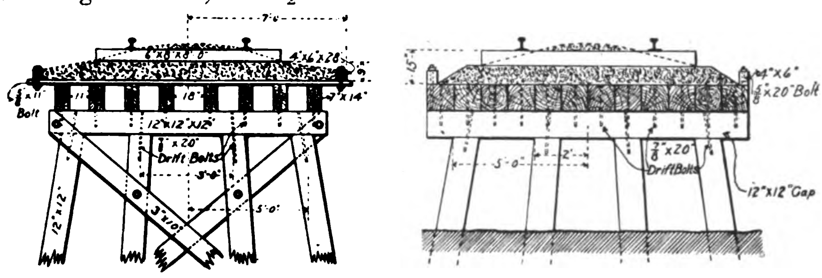
Fig. 449.—Forms of Buckled Plate for Bridge Floors.

shown, with the angles or channels capping the joints in the corners, to keep out water. In *D*, however, the top plates of the ridges might perhaps better be placed over the angle legs, as in Sketch *B*, the arrangement otherwise remaining as shown. Engraving *C* shows a section of floor with triangular-shaped troughs, being formed of angle bars and plates. This type of floor is in service on the Pittsburg, Ft. Wayne & Chicago Ry., in street viaducts in Chicago. As made on that road the top angle comes between the plates instead of capping them. Crushed stone ballast is used and the base of rail is 6½ ins. above the apex between the troughs. It is remarkable that the noise of trains passing over these bridges is not nearly as loud as the rumble that is heard from the solid plate or buckled floors where the rails are supported directly upon the metal.

Troughs with flat bottoms may be supported directly upon the flanges of the bridge girders, either at the ends of the trough or at intermediate points, but triangular flooring (Engraving *C*) is sustained at the ends of the troughs by angle lugs riveted to the web plate of the girder. Forms *A*, *B*, *C* and *F* are without seam or rivets in the bottom of the floor, so that tight riveting or calking to prevent leakage is not required. The joints are also better protected against corrosion. Drainage is usually provided by a weep hole in the bottom of each trough near each end, which drips into a gutter consisting of a channel running longitudinally under the floor, being suspended from hangers riveted to the troughs.

These gutters empty into down spouts leading to the pavement gutters or to the sewers.

The protection of steel plate in ballasted bridge floors from rapid corrosion is attended with considerable difficulty, as periodically the ballast must be dug out to uncover the metal for repainting or recoating. Consideration of this fact has resulted in the use of creosoted timber flooring for steel bridges on some roads. On some of the plate-girder bridges of the Chicago & Alton Ry. the floor for retaining the ballast consists of 6x8-in. creosoted timber laid on flat, side by side, across the top flanges of the girders. The ballast is 6 ins. deep under the ties. In order to carry the bed of ballast unbroken over the ends of the deck girder bridges, the abutment parapet is built up even with the top of the girder and the opening between the end of the girder and the parapet is bridged over by a metal plate. For drainage purposes some of the plate-girder bridges stand on a grade of 1 per cent, the difference of elevation in the ends of the bridge being evened up in the track by the difference in the depth of the ballast. On track-elevation viaducts where a shallow floor is required the creosoted flooring is only $3\frac{1}{2}$ ins. thick. The floor of the track-elevation bridges over street subways that is used by the Atchison, Topeka & Santa Fe Ry. consists of 12-in. 55-lb I-beams resting directly upon the bottom flanges of the plate girders, and spaced 16 ins. centers, covered with creosoted planks laid longitudinally with the bridge. The planks are dressed to a thickness of $2\frac{1}{4}$ ins. and are tongued and grooved. At the sides of the floor the planks, covering a width of about 18 ins., are laid to slope toward the center of the bridge. On the New York Central & Hudson River R. R. old bridge floor beams $16\frac{1}{2}$ ins. deep, covered with 4-in. plank, have been used in ballasted-top culverts of $13\frac{1}{2}$ ft. span. The Chicago, Burlington & Quincy Ry. is experimenting with a floor of reinforced concrete slabs 4 ft. wide, measured along the track, and $8\frac{1}{2}$ ins. thick.



HOUSTON & TEXAS CENTRAL RY. SOUTHERN PACIFIC RY.

Fig. 450.—Ballasted-Top Wooden Trestles.

Ballasted floors are also quite commonly in use on wooden trestles. The stringers may be planked over, as in the Houston & Texas Central ballasted floor, shown in Fig. 450, or the stringers may be laid touching side by side, as in the Southern Pacific ballasted floor, shown in the same figure. In the floor of the Houston & Texas Central Ry. there are eight 7x14-in stringers 28 ft. long, laid to break joints across the 14-ft. spans of the trestle. Across the stringers are placed 2x12-in. x 14-ft. flooring planks, along the outer edges of which are bolted 4x6-in. x 28-ft. curb pieces to confine the ballast. The track construction is ordinary and 9 ins. of gravel ballast is used underneath the ties. The tops of the ties, between the rails, are covered with ballast, as a means of protection against fire. In building new trestles creosoted lumber is used, both for the substructure and the superstructure, and, as such, it is regarded as very durable. It is found that expenses for repairs and renewals to trestles fall off very perceptibly as soon as the flooring and ballast are put on, and increased security is afforded the structure against catching fire from engines. The planks and stringers are separably removable and the track is worked by the regular section forces in the usual manner. In the floor of the Southern Pacific Co. the depth of stringer varies with the span, running from a depth of 6 ins. for a culvert span of 4 ft., to 12 ins. for a clear span of 14 ft. The piles are so driven that their center lines if prolonged would meet at a common point vertically over the center of the track, 25 ft. above top of rail.

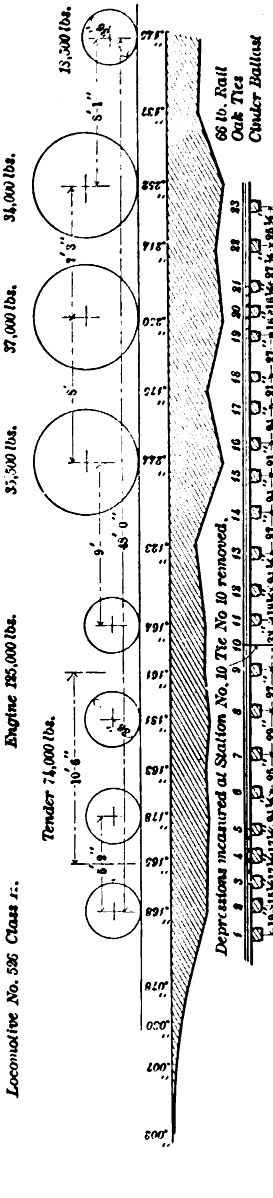


Fig. 452.—Experiments in Track Deflection (For Strain Diagram See Fig. 525).

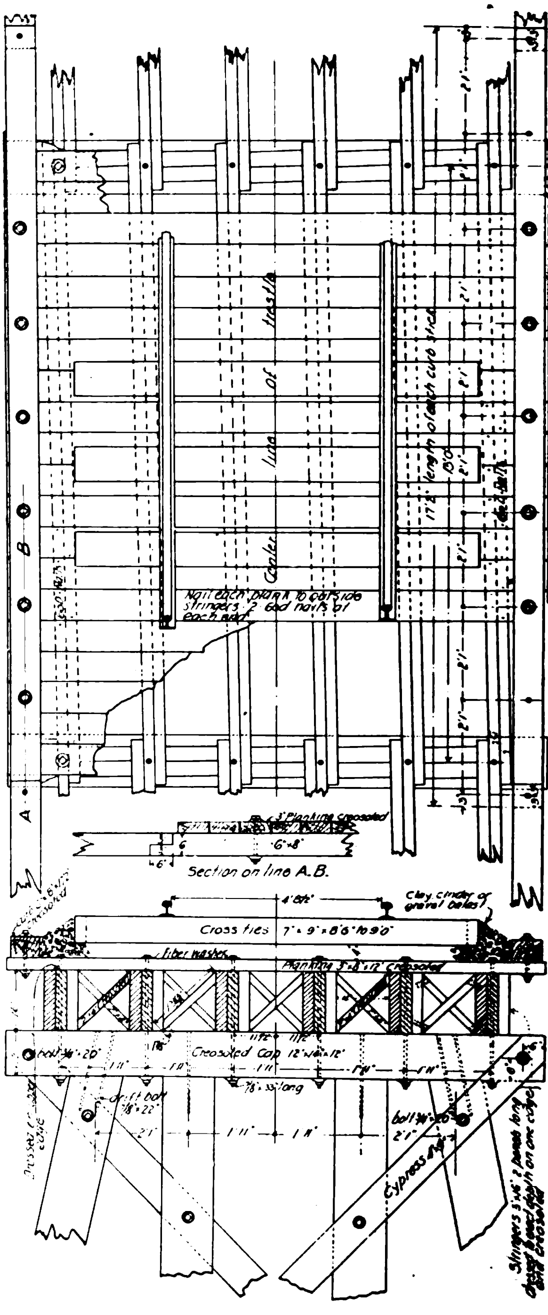


Fig. 451.—Ballasted Trestle Floor, Louisville & Nashville R. R.

The ballasted floor for timber trestles on the Louisville & Nashville R. R. has six stringers, each of which is made up of two 3x16-in. pieces dressed on one edge to exact depth and spiked together. The timber is creosoted, and the idea in building the stringer of two pieces is that they will take the chemical treatment more thoroughly than a solid 6x16-in. stick. The stringer pieces are two panels long and are laid to break joints and to lap by on the caps, as illustrated in Fig. 451. By this arrangement it is unnecessary to cut sticks at the ends that might be too long if required to meet on the caps. It is objectionable to cut timber or to mortise it for framing after it has been creosoted. Each stringer piece is held at the center by a long bolt passing through the floor and cap. The floor can be strengthened by putting in additional stringers without disturbing the ballast or existing stringers. Creosoted yellow pine trestles constructed on these plans were in sound condition after 24 years of service, and apparently good for a much longer life, having, since they were built, been strengthened by additional stringers in the manner stated, to enable them to carry heavier rolling stock.

Elevated Railway Floors.—As an elevated railway is essentially a trestle the type of floor for such bears a general resemblance to the floors of ordinary railway trestles. The floor in general use has plate-girder or lattice-girder stringers spaced 5 to 6 ft. centers and headed into the bents. The ties are laid directly upon the stringers and secured thereto by hook bolts. A guard timber, usually about 6x6 ins., is placed inside each rail, about 4 ins. clear of the gage line, and a 6x8-in. guard timber, laid on edge, is placed outside each rail about 8 ins. in the clear. Some of the elevated railways in New York have the inside guard timbers protected on the upper corner by a strip of iron. It is usually considered, however, that where a timber guard stands close to the rail metal protection is not needed, as a wheel cannot bite into timber unless it can strike it or meet it at a considerable angle. On elevated roads there is hardly room between the main rails and the guard timbers for the wheels to slew around to do this. The superelevation on curves, which rarely exceeds 3 ins., owing to the slow speed, is obtained by taper ties. The inside guard timbers are omitted on curves, and an inside T-rail guard is bolted to the inner rail of the curve, with cast separator blocks, maintaining a flangeway of about 2½ ins. It is usual, also, to back up the running rails and guard rail with braces. The track construction of the Union Elevated Ry. in Brooklyn has stringers or girders spaced 6 ft. apart. The ties are 8 ft. 3 ins. long and 7 ins. deep. The outer guard timber is 7x8 ins. in section, laid on edge, with the inner side 11 ins. from the gage line of the rail. The inner guard is 6x6 ins., spaced 6 ins. clear of the rail. The floor is secured to the stringers by hook bolts passing through the outer guard timber and tie. In the old system of track construction on this road the outer guard timber was 6x8 ins. in section, spaced 6½ ins. from the gage line of the rail and the inner guard timber was spaced 3½ ins. clear of the gage line. The floor of the Northwestern and Loop Elevated railways in Chicago has 6x8-in. ties 8 ft. long laid directly upon girders spaced 5 ft. centers. The ties are laid on flat and spaced 14 ins. centers, and hook bolts are used. The inner guard timber is 6x6 ins., laid 4 ins. clear of the gage line of the rail and the outer guard timber is 6x8 ins. in section, laid on edge and spaced 9¾ ins. from the gage line of the rail. Thus the wheel runs between two timbers, in a rut which is 13¾ ins. wide. The conductor rail is laid 20¼ ins. from the gage line of the running rail, on one side of each track, in the midway, and is lag-screwed to an insulating block which stands 1 in. clear of the outer guard timber. The space between the tracks is covered with four planks 8 ins. wide, laid 1 in. apart, to serve as a walk. On the Boston Elevated Ry. the outer guard timbers (6x9 ins., laid on edge and dapped over the ties) stand $10\frac{1}{2}$ ins. from the gage line of the rail, which is of 85-lb. Am. Soc. C. E. section The inside guard timbers (6x6 ins.) stand 4 ins. clear of the gage line. The near side of the head of the conductor rail stands 19 ins. from the gage line and the top of this rail is $11\frac{1}{2}$ ins. above top of tie. The conductor rails for both tracks are in the midway, with the feeder box, covered by a walk 34 ins. wide, between them. On sharp curves a 100-lb. T-rail is used for a guard rail, being considerably higher than the 85-lb. traction rail. Vulcanized yellow pine ties and tie plates are generally used in the floors of elevated railways.

154. Snow Fence.—In districts where the snowfall is not deep the principal difficulty with snow, if at all, is from drifting into the cuts, shallow cuts, as a rule, giving the most trouble. The cuts subject to drifting are those which lie across the direction of the wind, the snow which is carried being dropped into the eddy formed by the wind blowing over the top of the cut. A snow fence is an obstruction erected for piling up drifting snow, and it is used principally at cuts. If ground room is to be had it is placed across the direction of the prevailing winds, a sufficient distance back from the cut, on the windward side, to prevent the accumulated snowbank from extending into the cut. Where hard winds frequently blow from different quarters during the winter season it is sometimes necessary to have snow fence on both sides of the cut. The drifting snow is piled up on both sides of the fence. As the fence checks the velocity of the wind and turns it on an upward course it lets go of some of its entrained snow on the windward side, and that which is carried over drops into the eddy on the lee side or track side. As this side of the fence is shielded from the wind it is usually the case that the larger drift is formed on that side. On the windward side snow banks that slope 1 in 5 to 1 in 3, according to the velocity of the wind, are ordinary, while on the leeward side slopes of 1 in 17 to 1 in 8 are ordinary. As a general thing, deep cuts through mounds which rise abruptly need no protection, because after the wind blows the side of the hill bare but little snow will be carried to or over the cut. The force of the wind usually splits and the snow from the surrounding level is carried mostly around such a hill instead of over the top of it; and, from the upward currents caused by the hill, the snow which is blown over is usually carried high in the air, out of reach of the cut. But when the ground is level or gently sloping back from the cut for some distance, the snow which comes drifting hugs the ground closely and drops readily into the cut.

Stationary Fence.—The most common form of snow fence is an ordinary board fence, the boards in some cases being nailed to the posts horizontally, while in other cases the boards are placed upright and nailed to scantlings stretched between the posts. So far as results are concerned the merits of the two kinds are about equal. In cultivated or settled districts, where the right of way must be fenced at the place, the fence is usually made to serve both purposes—both a snow fence and a line fence. In this case the fence must be substantially built, and in any case the posts should be firmly set in the ground. If used only for snow, however, the posts need not be set nearer than 15 ft. 3 ins. for 16-ft. boards. The boards should be nailed on the windward side of the posts, overlapping, so that they may be easily taken off in case the fence is to be moved. In order to make it difficult for tramps and other persons to tear off boards the middle post of each panel is sometimes set on the opposite side of the boards from the end posts. Fence boards 1x6 ins. in size are commonly used, spaced 1½ to 6 ins. apart, and in some cases the boards are nailed on touching, so as to make the fence tight. Although it is not necessary to make a tight fence in order to pile up the snow, it is, in one way, at least, the most effective. Where the fence is made tight, eddy currents form on the windward side, and the snow will not pile up against it until the bank reaches the hight of the fence. The tight fence is therefore not so soon buried in the snow or drifted under. It is not necessary that the bottom board should touch the ground; in fact, as a measure of fire protection it should be placed about 1 ft. above the ground. If the first snowfall does not fill the gap the obstruction which the top boards offer to the wind will cause the snow to form a heap in the becalmed zone behind the fence, and accumulations to the front slope of this heap will gradually reach the lower board. In some cases the men fill this gap by throwing snow there before drifting begins.

As with line fence, so in building snow fence, there are, to be found here and there in practice, a considerable number of ways of making up the panels and bracing the same. At some of its badly exposed cuts the Intercolonial Ry. builds a fence 12 ft. high with upright boards touching edge to edge. Trial with boards spaced 1 in. apart and 2 ins. apart was not as satisfactory as the plan of putting them on close together. The round cedar posts stand 8¼ ft. apart centers and 8½ ft. high, and rest upon round cedar sills 8 ins. in diam. and 12 ft. long placed crosswise the direction of the fence and secured at the ends by stakes driven into the ground and by heaps of stones. The post is boxed into the side of the sill at the center, and spiked, and is knee-braced by two 3x5-in. x 10-ft. flattened cedar pieces let into the sides of the post and sill 1½ ins. and spiked. The 1-in. spruce boards are nailed to three 3x5-in. flattened cedar girts let into the posts and spaced 3½ ft. apart centers, the bottom one being 12 or 15 ins. from the ground. Another style of snow fence that is built for a fixed position, though not frequently found, is a stake and rider structure of poles or split rails. The fence is built by driving two stakes into the ground to cross each other, X-style, about 4 ft. from the ground. Into the crotch of these stakes a leaning pole or rail 16 to 20 ft. long is laid, with one end resting upon the ground. About 4 ft. from the first set of crossed stakes another set is driven to straddle the incline pole or rail and into this second crotch another pole is laid, inclined like the first and lying over it. The fence is extended by repeating the process. In lieu of poles, slabs from a saw mill, if available, serve the purpose even better. In Europe wire netting is sometimes used for snow fence. The posts are set permanently and the netting is put up at the beginning of each winter and taken down in the spring.

One of the most permanent forms of snow fence construction is a stone wall. In Europe stone wall snow fences are used to a considerable extent, being built to replace wooden fences as soon as experience has shown their proper position. On the Italian Meridional Ry. substantial stone walls 13 ft. high and 6 ft. 11 ins. wide on base, the sides battered 1 in 5, are doing service as snow fence. Walls 9 ft. 10 ins. high and lower are laid up dry with rubble stones, with a rounded concrete cap 19.6 ins. wide and 11.8 ins. deep. Walls higher than this are of dry-laid rubble except for a binding course of concrete 11.8 ins. thick, extending through the wall at the middle point of its hight, and a concrete cap of the dimensions stated. On some of the Hungarian railways there are stone wall snow fences 16½ ft. high placed 131 ft. from the edge of the cut. In this country stone walls are occasionally built for snow fences. The Union Pacific R. R. has dry rubble stone snow fence, about 5 ft. high, in a number of places.

On the Cape Cod division of the New York, New Haven & Hartford R. R. a stockade snow fence is made by setting old ties on end, in a ditch 2 ft. deep. By banking up at the ground line when the ties begin to rot off, the fence can be made to last 12 to 14 years, with good satisfaction. In this locality, where the ground is generally sandy, a day's labor will dig the ditch and put up about 25 ft. of this old-tie snow fence. The Minneapolis, St. Paul & Sault Ste. Marie Ry. and some other roads make use of the same kind of snow fence.

The effective hight of a snow fence is the hight of the structure above the ground less the depth of the fall of snow. The required hight therefore depends upon the ordinary depth of snowfall, for one thing, and upon the lay of the land for another. The hight of snow fence in service varies from 4½ ft., the ordinary hight of right-of-way fence, to 12 or 14 ft. where the drifting is bad. A hight of 7 or 8 ft. is ordinary. In any case the posts of snow fence should be longer than ordinary fence posts, so that additions to the hight of the fence may be made by nailing on more boards, if necessary. The direction of the fence should be somewhat across the path of the prevailing winds during winter time. In case, then, the wind strikes the cut at a slight angle, the fence, to be most effective, should be broken up into sections placed some distance apart, but parallel, and overlapping slightly when seen from the direction of the wind. At the end of the cut the fence should be extended beyond and turned toward the track, so as to guard the mouth of the cut against a quartering wind.

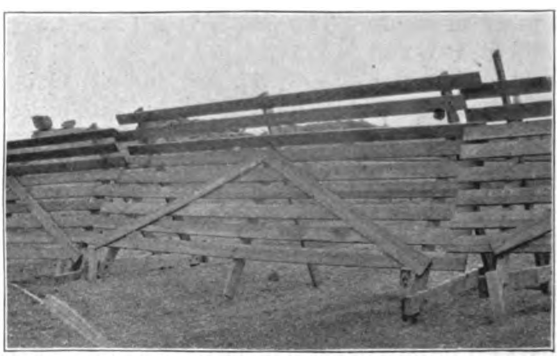


Fig. 453.—Standard Snow Fence, Union Pacific R. R.

The distance the fence should be placed from the cut depends upon local conditions, but usually 60 or 75 ft., or about 15 ft. away for every foot in hight of fence. It is well when placing snow fence at a cut for the first time to use a temporary or portable structure, or to build the fence only temporarily, nailing the boards to the posts rather loosely. After observing carefully the way the snow drifts for a few winters, it is possible that the fence may then be placed to better advantage, when it may be built permanently. If the fence is too near the cut the leeward snow bank will extend into the cut, and may cause the snow to drift deeper than it would without any fence at all; because in that case the cut would simply drift full, while with a snow fence too near, it might drift level with the top of the snow bank on the lee side of the fence. If the fence is too far away the current of wind deflected upward at the fence will drop before it reaches the cut, and whatever snow it carries will fall into the cut. The proper hight of the fence, as well as its distance from the cut and its direction, is also best determined experimentally, from observation extending over several winters. Fence that must be built too close to a cut for the best results should be higher and tighter than one that can be placed to best advantage.

With a view to the expediency of changing the direction of snow fence or its distance from the cut after experience with the local conditions may have shown such a change to be necessary, many roads have adopted a style of construction which admits of removal at only slight expense for labor and without doing material damage to the fence. Such fences are usually built in separate leaning panels with back braces in lieu of posts. An example of such construction is the standard snow fence of the Union Pacific R. R., shown in Fig. 453. It is about 7 ft. high and consists of diagonally braced panels of 1x6-in. boards, each leaning against three back braces (2x6 ins.), with three boards at the top nailed to the projecting ends of the back braces and leaning to windward. The panel posts and back braces are bolted together at the top and tied at the bottom by a plank bolted on, and spiked to stakes driven firmly into the ground. If the fence is placed when the ground is frozen the legs may be fastened with wire staples to drift bolts used as stakes. Where the wind blows unusually hard the fence is weighted down by piling stones upon the tie pieces. The pur-

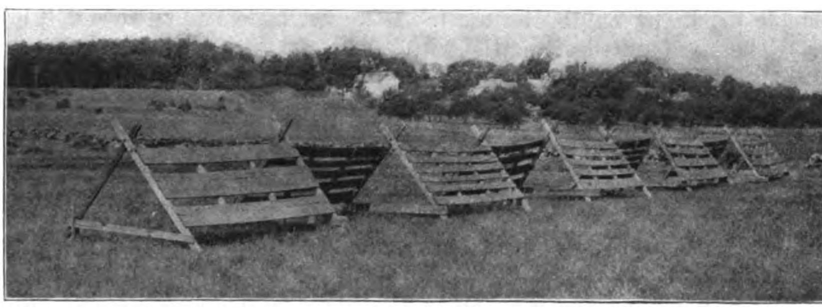


Fig. 454.—Portable Snow Fence, Boston & Maine R. R.

pose of the top projection to windward is to give the snow a back flurry and heap it up in front of the fence as much as possible. In setting up these fences on some roads it is the practice to leave 2-ft. spaces between the panels, thus to some extent economizing in the use of lumber.

Portable Snow Fence.—In regions of heavy snowfall and long continued winds a single line of snow fence is not usually found to be sufficient, for as soon as the snow bank which forms between the fence and track becomes as high as the fence, the fence then ceases to be of service. Where the winds have a good sweep it is frequently the case, therefore, that two or more lines of fence are needed, the second line being parallel with the first and generally about 100 ft. farther away from the cut. If the land bounding the right of way is waste land the second line of fence is usually made permanent, like the first, but if the land is cultivated a portable fence, in panel sections, is usually brought into service and put up temporarily during the winter. Again, the right of way on some roads is not wide enough to permit the building of even one permanent snow fence at a desirable distance from the cut to be protected, and in such cases it is usual to rely upon portable fences set up on private property temporarily during the winter season. A common form of portable panel is made by nailing 1x6-in. boards 16 ft. long to 2x4-in. x8-ft. scantlings, at each end and at the middle. The panel is held to position by 2x4-in. braces leaning against the panel posts and spiked or bolted to stakes driven into the ground. As the panels have to be handled over a good deal they ought to be strengthened with battens at the ends and middle.

A form of fence for portable use or for use permanently on rocky ground, where the expense for digging post holes would be a matter of some consideration, is shown in Fig. 454. This fence is simple in construction and is used on a number of roads. It consists of separate panels formed by spiking inch boards to 2x4-in., 2x6-in. or 4x4-in. scantlings, for end pieces and stiffeners. Alternate panels are then placed so as to lean against each other, or to and from the wind, in the manner shown. The end pieces of adjacent panels are crossed at the tops and bolted together and tied by a strip spiked across the legs at the bottom. The two end panels are maintained in position by a brace piece bolted to the top of the end piece and tied across the bottom by a strip, as in the case of the intermediate panels. On some roads a back brace is also used at the middle of each panel. To take the fence down it is only necessary to knock loose the tie pieces spiked to the bottoms of the legs and unbolt the end pieces at the top. Another scheme for a portable snow fence, that has been used on the Chicago & Northwestern Ry., is to build separate panels of boards and wire them fast to the posts of the wire fences during the winter season.

The Pittsburg & Western Ry. (Baltimore & Ohio R. R. system) builds portable panels by nailing boards to A-frames made from two old bridge ties. These are united at the top with a bolt and tied across the bottom by nailing on a strip 5 ft. long. At one time the Chicago & Eastern Illinois R. R. used a portable snow fence made entirely of 1x6-in. fence boards. The panels were 16 ft. long and seven boards high, spaced 1 in., 2 ins. and 3 ins. apart, with battens 8 ins. from the ends of the panel and a bracing cleat running between diagonally opposite corners on each side of the panel. At each panel point in the fence the two panels were headed into and hung upon a braced standard placed at right angles to the fence. This standard consisted of two upright boards 4 ft. 8 ins. long and 3 ins. apart, nailed at the bottom to the middle of a horizontal board 8 ft. long, and knee-braced to the ends of the same. In setting up the fence the ends of two adjacent panels were inserted between the two upright pieces of the supporting standard, lapping by each other, the bottom board of the panel and the one next the top being cut off at the batten where they came in the way of the horizontal piece of the standard and the top ends of the knee braces where they were spiked across the two upright pieces of the standard. Each panel was supported at the under edge of the top board, resting upon the two knee braces where they crossed the 3-in. space between the upright pieces, 6 ins. from the top of the standard; and at the under edge of the board next the bottom, resting upon the horizontal piece of the standard. When portable fence is removed from the fields in the spring it should be carefully piled or stood up in a leaning position, and to protect it from fire the grass should be kept from growing around the piles or stacks. In dry regions a layer of dirt is sometimes spread over the top of the pile of panels to protect against fire.

The number of lines of snow fence required depends upon the quantity of the snow, for the second fence (from the cut) serves to catch and hold snow which would be sure to drift against the first fence. At some points on the Union Pacific R. R. the snow fences are as many as five and six lines deep, one in advance of the other, at distances of 75 to 200 ft. apart. In several places on this road snow fence is placed at a much lower level than the track. At one point there are three lines of snow fence on a steep side hill, lower than the track, which is in a side-hill cut. Such protection is necessary where the sweep of the prevailing winds up these side hills is sufficient to carry snow up into the cuts.

The same result that may be obtained by the use of two or more lines of snow fence may be accomplished by using portable fence on top of the snow bank formed at one fence, or even by the use of a portable fence alone. As soon as the accumulation of snow attains a hight level with the top of the fence the practical utility of the latter ceases, and the furrow in which the fence stands, between the windward and leeward drifts, becomes rapidly filled up. Before the fence becomes buried, however, it is taken up and placed upon the summit of the leeward drift, when it again becomes effective. By transferring the fence to the top of the new leeward drift each time that the drifts each side of the same cease to increase in hight or volume, the repetition of the process will in time form a bank so high that the wind will be carried past the cut before falling to the surface level. It is also frequently the practice, where repeated storms have filled the fences, to build walls of snow as substitutes for portable fences, the snow being taken from the track side of the wall and heaped up to a hight of 4 ft. or more. In a hard wind snow walls, unless protected in some manner, will be blown away. Such protection may be arranged by topping out the wall with a fence board nailed to two stakes driven into the snow. Snow walls will sometimes endure several days of thawing weather after the surface snow has melted away, and remain to do service in the next storm. A good deal of labor is required to build them, however, and they should be regarded only as an expedient, when portable fence is not quickly available. In some parts of Europe where land is more closely utilized than in this country, the width of the right of way is very narrow and the permanent snow fence must be built at the edge of the cut. In a case of this kind the whole of the drift has to be put on the windward side of the fence. Such is the case with some of the snow fences on the Paris, Lyons & Mediterranean Ry., in France, and in some instances portable fence is relied upon altogether. Before the snow starts drifting a wall of snow is built at the proper distance from the track, the snow being taken from an excavation on the track side of the wall. As soon as a drift has formed in front of this obstruction a wooden screen about 5 ft. high is planted on top of the drift by driving boards endwise into the snow. When a new drift is formed as high as the top of the screen the boards are pulled up and set upon the summit of the new drift, the operation being repeated as often as the screen is drifted full. A temporary fence may also be built by laying up a wall of old ties, rail fence fashion, and such a scheme is frequently resorted to where lumber is not on hand. This fence can be put up quickly by the section men, and by picking out the soundest of the ties it may be made to last two or three winters. On rocky ground, where stakes cannot be driven the old-fashioned rail fence or worm fence can be used.

Hedge Fence.—If the nature of the soil and other conditions are favorable it is a good plan to set out along snow fence a hedge of evergreens, stub pines, or of such indigenous trees as grow bushy near the ground. Common balsam or cedar is good, where it will grow and thrive. By the time the board fence is decayed the trees will generally have grown sufficiently high to form a most efficient snow fence, which will need no repairs except, perhaps, an occasional trimming. In some localities where there has been difficulty in getting plants to grow, willows have been found to be the best. For the purpose of a snow fence it is generally recommended that the hedge should be planted in three or four rows about 8 ft. apart, the trees in one row staggered with those of the next row. The row nearest the cut should be at such distance as has been found proper for structural snow fence.

Comparatively speaking, hedge snow fence has received but scant attention in this country. Only a few roads have tried them, and on some of these the experiments have been disappointing. According to some authorities these failures have been due to a wrong adaptation in some respect, such as the selection of a plant not suitable to the soil or for the purpose of a snow fence, or to a wrong method of cultivation, or lack of watchfulness in trimming and protecting from fire. Along the Chicago, Milwaukee & St. Paul Ry. in southern Wisconsin cedar hedges planted on the right-of-way line at many of the cuts have attained a hight of 12 to 16 ft. Some of these hedges have been permitted to grow too high, and the foliage is so sparse near the ground that low board fences are necessary to prevent the winds from carrying the snow under. For the decoration of its station grounds and for snow fences at cuts and at other places where drifting snow might be bothersome the Philadelphia & Reading Ry. has made extensive use of the shrub California privet (Ligustrum ovalifolium). These plants are raised in the company's own nursery and set out when two years old, about 10 ins. apart. The first year they are not trimmed any further than that which they receive at the time of planting, but the next year they are trimmed in January or February, again in July, and again in the winter. The trimming is easily performed, as the wood is not hard like the Osage orange, which is used quite generally for hedge fence. As a hedge plant the privet is one of the most beautiful, as the leaves remain until late in the winter and it is an early thriver. It is trimmed to a hight of 6 or 8 ft. the growth is dense from the ground up, and its effect on the landscape is decidedly beautifying. For some time about 30,000 of these shrubs were raised each year for planting in exposed places for snow breaks. For hedge snow fence on the Intercolonial and Northern Pacific roads, see §219.

The most extensive use of hedges and tree plantations for snow fence has been in Russia, where such means of protection was adopted as early as 1865. On the Moscow-Nijni-Novgorod Ry., particularly, this kind of snow fence has been systematically experimented with and studied, and the results achieved have been highly satisfactory. In the north, northwest and western districts the trees planted are mainly coniferous—firs and pines—but occasionally white firs mixed with birch in the proportion of one to four. On 16 lines of railway, trees of these kinds are being cultivated, and on only three of these lines (which are in the south and center of Russia, where it is difficult to acclimatize conifers) have the results been unsatisfactory. With these exceptions coniferous trees, if planted at the proper distance from the track, give the desired protection. On the road named (where the right of way is 350 ft. wide) the trees are set on the boundary line, 175 ft. from the track. In the majority of cases the fences are formed of two or three rows of trees, but frequently there is only one row, and sometimes as many as six and even ten rows. As a general thing these plantations begin to be useful after seven to ten years of growth. Saplings transplanted from nurseries have given better results than those taken direct from the forest.

The culture of the conifers is usually undertaken by the railways themselves, a small nursery being attached to each roadmaster's district. It is rarely the case that large nursery grounds are maintained or that special services are called in to supervise the cultivation of the saplings, or that trees are purchased from outside. The aim is to have the nurseries so widely distributed that the plants needed at any point will not be longer than 24 hours in transit. In the majority of cases the firs appear to be the most suitable species, but in some parts white Siberian or Polish pines are preferred, and in sandy soil the pines flourish best. The pruning of the conifers is commenced when they have attained a hight of about 28 ins., being usually attended to in the autumn. The purpose of this early pruning is principally to keep the trees at a uniform hight and to thicken the branches and develop the foliage close to the ground. As the trees increase in size the front of the fence is trimmed to slope toward the bottom, like the side of a battered wall. Where the snow drifts are usually of moderate size the trees are trimmed to a hight of about 4½ ft., but for heavy duty the hight is not less than 9 or 10 ft., while on some lines the trees are allowed to grow to full hight, as in the forest. The cost of a mile of fence set with conifers ranges from $40 to $275, according to the number of lines of trees and the conditions peculiar to the location.

On the steppes of central and southern Russia, where conifers do not thrive, the experiments with leafy trees for snow breaks have been very numerous and frequently have been carried out on an important scale. In these trials the degree of success has not been uniformly so good as in the experience with conifers in the North and West. Black and tartar maple, elm, ash, hawthorn, willow, osier, sorrel thorn, mulberry and red alder are some of the trees used. As the trees during the winter are leafless and open they fill up with snow, and if close to the track afford no protection. In any case a large number of rows of trees is required to stop the snow, various authorities putting it at 15 to 32 rows, set close together and a good distance from the track, the first row to be not nearer than 70 to 100 ft., according to the local topography. Where the number of rows is comparatively small the best results are obtained by alternating the rows of trees with rows of bushes, always having bushes in the outside rows. White, yellow and German acacia, wild olive and honeysuckle are some of the bushes employed. On the St. Petersburg-Warsaw line a combination of willow and birch is fairly satisfactory, but they afford less protection than conifers. On other lines 10 rows of white acacia, in one instance, and 20 rows of red alder, in another, have also proven satisfactory. On the Hungarian State railways three rows of wild roses, the plants staggered in the different rows and trimmed to a hight of 6½ ft., have given good protection, and acacias have done fairly well.

In shallow cuts of 3 or 4 ft. or less depth it sometimes pays better to grade down the banks than to build and maintain snow fences. By running the slope back 60 or 70 ft. on each side of the track, or even 1 in 10 for the heavier work, the wind will drop and blow the cut clear. If there are hollows near such cuts the work may be cheaply done with plow and scraper. Material near the track may be loaded and used to fill in bridges or be wasted on embankments. Snow fence is sometimes made by heaping up earth, and if the material may be had by excavating for a slope ditch it would seem that the plan ought to pay. The Union Pacific R. R. has followed quite extensively the plan of grading back shallow cuts on easy slopes and piling the dirt up at the proper distance to form snow breaks. In other instances dirt or rock taken from deeper cuts that have been excavated to ordinary lines has been disposed of in the same manner. Some of the roads in the northern part of the Mississippi valley have used sod walls 4 or 5 ft. high for snow fence.

In a flat country some attention should be paid to the hight of the track above the surrounding level. As long as the rails are higher than the snow on the ground immediately to the windward the track will be blown clear while snow is drifting, but as soon as the depth of the snow exceeds the hight of the rails above the general level the track is then virtually in a cut, which will drift level full in short order as soon as the wind starts blowing; and a depth of a few inches of fine, closely compacted drifted snow is a greater hindrance to traction than several times that depth of snow which falls in place. On prairie land where hard snow storms are to be expected the hight of the roadbed should therefore be such that the rails will stand above snow of the ordinary depth on the surrounding level For sake of illustration, suppose that on the plains in some certain locality the depth of snow to be expected with more or less regularity is 2½ ft. on the level. It is not at all necessary to assume that snow of that depth would fall during one storm. Allowing 5 ins. for depth of rail, 7 ins. for depth of tie and 8 ins. for depth of ballast, we get 20 ins. from sub-grade to top of rail, leaving 10 ins. as the hight of the embankment which is necessary to put top of rail even with the top of the layer of snow. In such a case it ought to be more than 10 ins.—say 15 or 16 ins.—so as to allow for snow thrown to the side of the rail by engine pilots and snow flangers. As already explained, the speed of snow plows on open track should be such that the snow will be thrown well clear of the shoulders and not heaped up at the side of the track. A ridge of snow at the side of the track is just as detrimental in the way of stopping drifted snow as though the track stood in an earth cut of the same depth.

In Russia, where there is much level country and where the accumulations of snow during the long winters are a serious difficulty to contend with, this question of providing against snow drifts over slightly elevated embankments was long ago investigated in a thorough manner and settled by government authority. In the schedule of conditions for the construction of new lines, as laid down by the ministry of ways of communication, is a stipulation requiring that the hight of embankments in places exposed to snow accumulations shall not be less than 25.2 ins. (0.3 sagene), except when passing from cuttings to embankments. With the usual allowances for ballast this requirement places the rail head 3 ft. 2 ins. to 3½ ft. above the ground level, but on some of the railways where the fall of snow is excessive the managements, from their own choice, prefer to make the embankments even higher than the government requirements, in order to obtain desired protection from drifting snow.

Certain abnormal conditions of location or of the winds have in cases suggested the trial of odd arrangements in snow fence. When the direction of a wind is straight through a cut it will blow the track clear, but when it strikes at a small angle the formation of long drifts diagonally across the track may sometimes occur. One can imagine how the winds might pick up enough snow between the track and the fence to form drifts of good size once it is blown down into the cut, or the wind might veer so far from the prevailing direction as to blow between diagonal fences set to overlap in the path of the prevailing winds. Again, when snow-bearing wind blows into a curved cut the change of direction may reduce the velocity and cause it to drop its snow in the artificial calm to windward, forming long and narrow drifts on the track. And then, the direction of a cut may be such that the prevailing winds come at a small angle, and if they change around considerably some of the snow behind the fences may be blown into the cut. On the Concord and White Mountains divisions of the Boston & Maine R. R. wing fences have been tried in some of the cuts to meet such conditions. At certain points where the track runs due north and south, or nearly so, the prevailing winds (northeast) blow into the cuts in a quartering direction. A few days after a storm has cleared off the wind may veer into the other quarter (northwest) and blow into the cut from the opposite side. The arrangement for protecting such cuts consists in running short wing fences or panels down the slopes of the cut, as far as the ditch, at an angle of about 45 deg. with the track. The panels of wing fence are separated by intervals of 60 to 90 ft., and are placed alternately on either side of the track, the idea being that when disposed in this manner they stand at right angles to a quartering wind blowing from either side of the cut. These fences, although tried for a long time, have been rather disappointing. When the wind blows in certain directions long bars of hard snow 2 to 4 ft. deep will form on the track, running from the panels of fence like windrows, so to speak. Sometimes these drifts are almost as solidly compacted as ice and it is a hard pull for engines to get through. These fences, which are often referred to in discussions on snow fence, were illustrated in the Railway and Engineering Review of Nov. 4, 1899.

As any obstruction which will form a calm in the wind currents will cause the formation of a snow drift, it is seen that buildings and other structures to the windward may cause the track to be obstructed in much the same manner that drifts are deposited behind snow fence. The following instructions issued in anticipation of trouble arising in this way are found among the rules for location and construction of the Northern Pacific Ry.: "In regions swept by strong winds, where the snowfall is liable to be great and drifting to occur, all structures will be put on that side of the track opposite the prevailing winds. Usually this will be the southerly side, and station buildings, water stations, switch stands, and every kind of structure that can cause the formation of drifts, will be put on that side. Sidings and spur tracks should be put on the same side, where practicable." On some other roads track and bridge men and other employees are instructed to pile no ties, timbers or other material on the windward side of the track so close that drifts formed behind the piles might extend to the track.

There are some situations other than those mentioned hitherto which require protection by snow fence, such as turntable pits at exposed points, and round about the mouth of a tunnel, to prevent snow from blocking the entrance or the cut leading up to it. At the east end of the Aspen tunnel, on the Union Pacific R. R., there are three lines of snow fence running around the side of the mountain, above the entrance to the tunnel. In desert regions, such as are found in the southwestern part of this country, the sand drifts and forms into heaps in a manner very similar to that of drifting snow, but is more dangerous to train operation, and fences have to be built to keep the track from being covered by sand. Such fence is built on the same principle as a snow fence. On some roads running near the seashore the same conditions prevail. Along some portions of the Trans-Siberian Ry. drifting sand gives a great deal of trouble, and in such places a line of shrubs is planted, wherever they can be made to grow As a further protection a strip of wild oats is sown along both sides of the track. The Southern Pacific Co. has a special standard section for roadbed requiring protection against damage by sand storms. The track is filled in with sand to a level 1 in. above the tops of the ties and in cuttings this level is extended out 4 ft. beyond the ends of the ties. On embankment the shoulder is filled up to the same level and carried out 3 ft 8½ ins. from the rail. For the protection of slopes, to keep the sand from blowing away, rock, heavy subsoil or brush with butts well embedded and branches about flush with the face of the slope, is used. Where stone of the proper size can be obtained they are placed on lines 3 ft. 8½ ins. from the rails, on embankments. The use of a layer of cinders or of clayey soil, and the planting of Bermuda grass and other vegetation for the protection of sand slopes from the wind are elsewhere referred to.

155. Snow Sheds.—In mountain regions where the snowfall is heavy and deep drifts and snow slips are liable to occur, such as in deep cuts and along side-hill slopes, the track must be protected by snow sheds. Such structures are formed over the track by framed bents of heavy timbers covered with planks on top and at the sides. On side-hill where snow slides are liable to occur the up-hill side of the shed is built to form part of a slope extending from the hillside over the top of the shed. In case unusual trouble is looked for in this direction the space behind the shed is filled in with a heavy masonry wall (Fig. 457) or rock cribbing and the crib is covered with timber or earth filling, to form a firm slope on the up-hill side of the shed. In some cases the bents are anchored to the rock with long tie rods. In addition to this heavy V-shaped or diagonal stone-filled cribs are sometimes constructed higher up on the mountain side, to split the slide or to turn it aside.

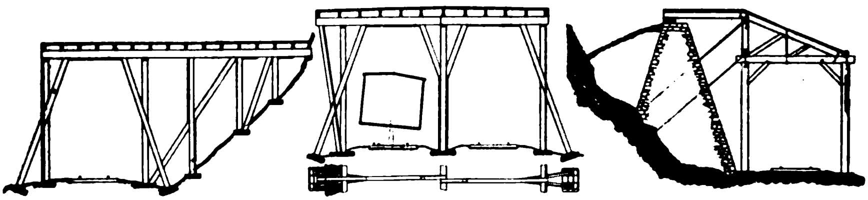


Fig. 455. Fig. 456. Fig. 457.
Types of Snow Sheds, Central Pacific R. R. (S. P. Co.).

On the Central Pacific line of the Southern Pacific Co. there are 36 miles of snow sheds. Of this 28.49 miles of shed is continuous, being broken only over bridges. Sheds of the latest design measure on the inside 20 ft. high from top of rail and 16 ft. across from post to post. The bents are constructed of 8x10-in. posts, 8x16-in. beams and 5x10-in. braces. The bents are placed 6 to 8 ft. apart, according to the quantity of snow, which in some places frequently lies 25 ft. deep. The roof planking is 3 and 4 ins. thick and the side boards $1\frac{1}{2}$ and 2 ins. thick. In the latest structures the roofing is redwood and the remaining lumber mountain pine. Figures 455 to 458, inclusive, illustrate types of construction, Fig. 456 showing the arrangement where there is a side-track. To admit light and air a narrow opening is left in the side planking near the top, as indicated in Figs. 457 and 458. Figure 459 shows types of strong crib construction that are used on the Denver & Rio Grande R. R. At a place on the Southern Pacific road in northern California a shed was at one time constructed in a troublesome side cutting to carry sliding earth and rock over the track.

The Canadian Pacific Ry. is another line that encounters very deep snow. At Hector, in the Kicking Horse River pass, near the summit of

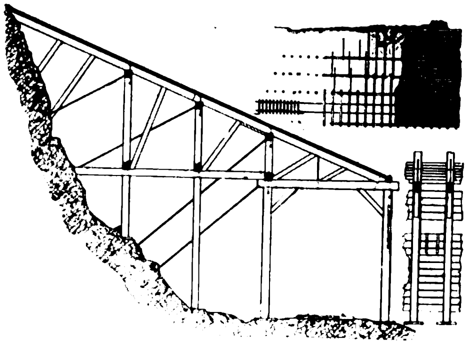


Fig. 458.—Snow Shed, Cent. Pac. R. R.

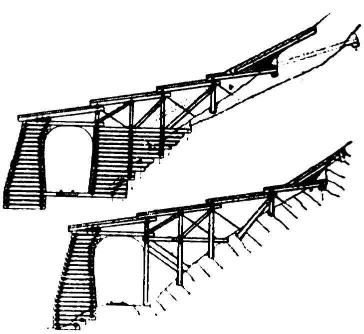


Fig. 459.—Snow Shed, D. & R. G. R. R.

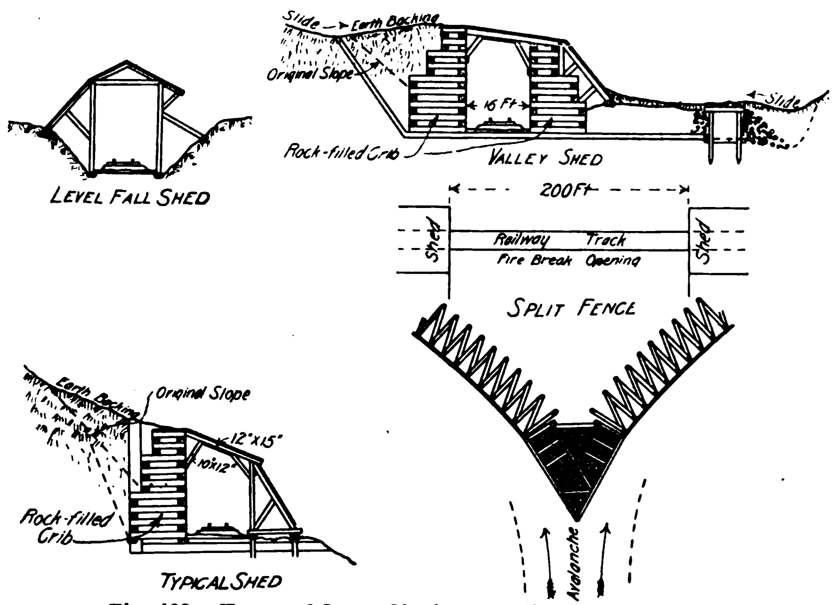


Fig. 460.—Types of Snow Sheds, Canadian Pacific Ry.

the road in the Rocky mountains, snow falls in every month during some years. Records kept by the watchman at this point for a number of years show an average annual snowfall of 27 ft. 4 ins., the minimum being 23 ft. and the maximum fall during any year 41 ft. In the Selkirk range, to the west, the snowfall is even more remarkable, the average for a number of years at the station at Glacier House, B. C., being 31 ft., and in a single year 43 ft. 8½ ins. In the Rocky mountains the snow is generally handled with rotary plows, without serious difficulty, but in the Selkirks, where avalanches are of frequent occurrence, bringing down immense masses of snow mingled with rocks, mud, tree trunks and other debris, machinery is powerless to keep the road open and many miles of snow sheds are necessary. Points that are not liable to be covered by avalanches or deep drifts are left unprotected and are kept open by the rotaries.

Types of snow-shed construction on this road are illustrated in Fig. 460. The so-called "level-fall" shed is placed at points where the road must be protected from drifts but where avalanches are not expected. The "typical" shed is built at points along the sides of valleys where avalanches can come from one direction only. The "valley" shed is employed in the bottoms of valleys where avalanches may descend from either side. In narrow valleys avalanches do not always stop in the bottom, but frequently sweep some distance up the opposite side, doing damage from an unexpected direction. Cases are on record where laborers on the track have been killed by not heeding an avalanche sweeping down the opposite side of a valley which they supposed was so far below that the avalanche could never get up to them. In the heaviest work the bents are built of 12x15-in. Oregon pine timbers securely braced and drift-bolted together, and are spaced about 5 ft. centers. Wherever the lay of the land is favorable, the ground above the shed is cleared and graded up, with the object of giving the avalanche an upward turn and shoot it across the track without striking the shed with full force. Glance and split fences, built as cribworks of logs, are also used, in places, along the mountain side, to turn the avalanches into ravines, where they will pass under the track, or to split up the avalanche and break its force. Avalanches of dry snow descend with great velocity (greater than that of wet snow) and the currents of air set up by the swift motion of the huge mass often do more damage to railroad property than the avalanche itself, as they may extend over a wide area. These currents are locally known as "snow flurries," and are sometimes attended with the force of a cyclone, snapping off the trunks of full-grown trees. These "flurries" have been known to sweep away bridges which were not touched by the avalanche of snow passing underneath. One bridge on this road was swept away six times in this manner, and was finally replaced by a masonry arch, which has been able to stand firm.

To guard snow sheds against fire several systematic measures have been adopted. Where it is necessary to protect a long stretch of track it is the practice of the Canadian Pacific Ry. to break the shed into comparatively short sections, with open spaces of 200 ft. between them. To protect these openings V-shaped "split fences" of heavy cribwork (Fig. 460) are built on the hillside above, to deflect the avalanche to the right and left and cause it to pass over the sheds. These open spaces also serve as ventilation openings, to quickly clear the sheds of smoke, which in winter, when all the small openings are covered with snow, would otherwise be slow to escape. At some of the sheds there are also systems of piping with hose attachments, or sluices, leading water from high streams above the tops of the sheds, where the watchman can use it in case of fire. At many places there is an extra or "open-air" track outside the shed to carry the traffic in summer, the object being to reduce the fire risk, avoid the smoke and give passengers the benefit of the mountain scenery. The Central Pacific line has special trains equipped with water tanks, fire pumps, hose, etc., for fighting fire in the snow sheds. These trains are held in readiness, with crews ready to go at a moment's notice. The worst fires to contend with are forest fires, which sometimes burn down long stretches of shed in spite of all efforts of the fire crews. Another means of fire protection in the construction of the shed itself is to side up the structure at intervals with galvanized iron in place of planking, and this road has also movable or telescopic sections of shed 50 ft. long, at intervals, which are run inside the stationary shed during the summer season, leaving gaps in the structure. These movable sections stand on wheels, on a track of 16 ft. 8 ins. gage.

Some of the European railways, particularly the Arlberg line of the Austrian State Ry., have gone to great expense to protect the track against avalanches. One method is to erect a series of walls or piers of various kinds on the slopes above the line, to reduce the speed of moving bodies of snow, break them up and divert them into separate portions, which checks their momentum and scatters the tremendous force of the original mass. The Arlberg line builds thick cemented stone walls in some places, and in other cases a double line of old rails is driven into the ground and filled in between with logs and poles. The two rows of rails stand 3 ft. apart and the rails, which are 3 ft. apart in each row, stand 7 ft. out of the ground. Rock-filled log cribs are also used, as in this country. It has been found that the most effective way of preventing danger from avalanches is to place the means of protection where the avalanches are formed, and the most satisfactory method is to set out trees on the slopes to prevent the snow from getting started. The Arlberg line has not only taken up the work of planting trees on an extensive scale, but has also adopted the policy of acquiring existing forest and wooded slopes along the line, in order to prevent removal of the timber prematurely. The old timber is cut down and used in protective works and young trees are planted to take its place. In reafforesting slopes where the timber has been felled irrationally, both pines and deciduous trees are planted. At some points on the Hungarian State Railways it has been found necessary to extend the arches of tunnels for some distance into the approach cuts, in order to protect them from deep snowfalls and sliding snow. These arches are of masonry construction, of the same curvature as the tunnel lining, and by filling over the top with stones they are made strong enough to withstand sliding earth and rock.

Where a snow slide crosses open track it will fill up the side-hill cutting occupied by the track and pack it very hard with snow, rocks, tree trunks and other debris which a snow plow cannot clear away. In some cases snow slides have been known to fill up one side of a valley, covering the track with such a large pile of debris that it was necessary to build a detour track to get the traffic past. An avalanche at Ophir, Colo., on the Rio Grande Southern R. R., Feb. 20 1897, cut over 10 acres of timber 10 ins. to 2 ft. in diameter and struck the depot, which was built of strongly

Fig. 460 A.—Avalanche at Ophir, Colo., Rio Grande Southern R. R.

framed bridge timber. One end of the building was carried completely away and the remainder was shoved 15 ft. and buried up in a mass of snow rocks, trees, etc., six large tree trunks being driven entirely through it. Four loaded box cars were carried 600 ft. from the track. The avalanche traveled $1\frac{1}{2}$ miles from the top of the mountain, nearly a third of the distance being through timber. It took 30 men and four locomotives 38 hours to dig the track out and pull timber and rocks out of the way. Figure 460A shows one of the engines pulling trees off the track.

156. Fire Guards.—Destructive fires started by sparks from locomotives often run over large areas, especially through the stubble of grain fields in the prairie states. It is therefore incumbent upon the railway companies to take some means for guarding the abutting property from fire, as far as possible, wherever the conditions are threatening. A fire guard is made by plowing several furrows, usually four or five, parallel with the track, at such a distance from the track that sparks will not be blown beyond them, generally from 100 to 150 ft., but sometimes 200 ft. This distance ordinarily brings them off the right of way; but as they are made for the benefit of the people living along the line no well-disposed person objects to the use of his land for such purpose. It is a good plan to burn over the ground between these furrows and the track. When no wind is blowing or, better, when a light quartering wind is blowing toward the track, the section crew should set fire to and burn off the windward side, keeping watch near the furrows and the track. Wind will carry the fire along quite rapidly, and, coming from almost any direction, will usually favor either one side or the other of the track. If it is blowing parallel with the track and not too hard, both sides may be burned at the same time If no wind at all is blowing fires may be kept going at several places, so as to get over the ground more rapidly. In places where much anxiety is felt regarding fires a second line of furrows is made beyond the first and the ground burned over between them. The ground between the first line of furrows and the track need not then be burned over. The plowing of fire-guard furrows is frequently let by contract, and continuous furrows as long as 70 miles have been plowed, a six-horse team making about 25 miles per day with one furrow in hard prairie soil. It will usually take less time to watch and burn over the dry grass, etc., around wooden bridges and other track structures than will be spent in running to put out fires every time they get started.

157. Bumping Posts.—Obstructions to prevent cars from being pushed off the ends of spur or stub tracks are of two kinds: viz., wheel stops and bumping posts. Too frequently, such devices are badly used, and often the damage caused by their presence is much greater than would be the cost of pulling a car onto the track occasionally. Nevertheless, to provide for conditions which sometimes make it a necessity, such, for instance as when there is a failure of brakes to act (when there is such a failure in fact), slippery rails, grade in the track either way, mischievous boys, etc., it should be used. The logical idea is that the post should come into service only in event of the failure of a brake chain or through some other uncertainty, and that it should not be put to "general use," as is frequently the case. In a spur where the track is level and there is room beyond the end of the track it is not worth while to go to much expense in putting in a bumping post, because there is not really any need of it; and the stronger the bumping post is made on such track the harder will some juvenile trainman send cars against it and try to knock it out, just for amusement. There is not quite so much sport in pushing or running a car off the end of a spur track as there is in sending it against a bumping post, and as a usual thing trainmen are more careful in handling cars on tracks without bumping posts than they are where bumping posts are provided. Where there is room beyond the end of the track, so that no particular damage will be done by cars which may be run off the end of it, it is largely the practice to dispense with bumping posts. In order to facilitate the work of hauling the cars on again it is the practice with some roads to spread the rails apart, about a foot wider than the gage, at the end of the track, and to lay a plank inside the flaring end of each rail to receive the wheel as it drops from the rails. In pulling the car ahead the convergence of the flaring rails serves to bring the wheels readily onto the track again. Where cars have to be thrown up grade into a spur, by a "flying switch," a bumping post is needed, because the car must be given a good start and it is not always so easy to judge of the proper speed required. Where the grade of the spur descends from the main track there is no necessity for throwing cars into it at much speed, but to provide against the contingency of the brakes being let off standing cars there should be some kind of stop to hold them; likewise, when coupling cars on such a spur, sometimes the starting of a car cannot well be avoided.

About the best all-round stop for out of doors, where there is plenty of room, is to cover the last 15 or 20 ft. of the track to a depth of 2 ft. with cinders, gravel or sand. Cinders is the best material, because it does not freeze hard in winter. This arrangement will stop cars at considerable speed, it is easy on the cars and is comparatively inexpensive. The standard car stop of the Southern Pacific Co. is a heap of earth or sand retained on three sides by a plank box 10 ft. square and 22 ins. high. This box is open on the side where the track enters, and is formed by spiking 3-in. plank of durable timber to the inside of 6x8-in. posts 5 ft. long, set at the corners of the box. The rails extend about half way through the heap. This is the type of buffer used for permanent spurs at principal stations. At points where something better looking is required there is a heap of earth or cinders walled in on sides and rear with concrete. The stop shown in Fig. 461 is 12 ft. wide over side walls, and 11 ft. long. The walls are 9 ins. thick and the heap of earth, which in this case happens to be adobe sand, is 3 ft. high above top of rail. The standard buffer for temporary spurs and for use at unimportant stations is a truncated pyramid of earth 15 ft. square on base, 5 ft. square on top and 3 ft. high, the track running into the heap about 5 ft. The earth buffer of the Chicago & Northwestern Ry. is a heap of cinders or dirt a rail's length beyond the end of the track. Between the end of the track and the heap there is a

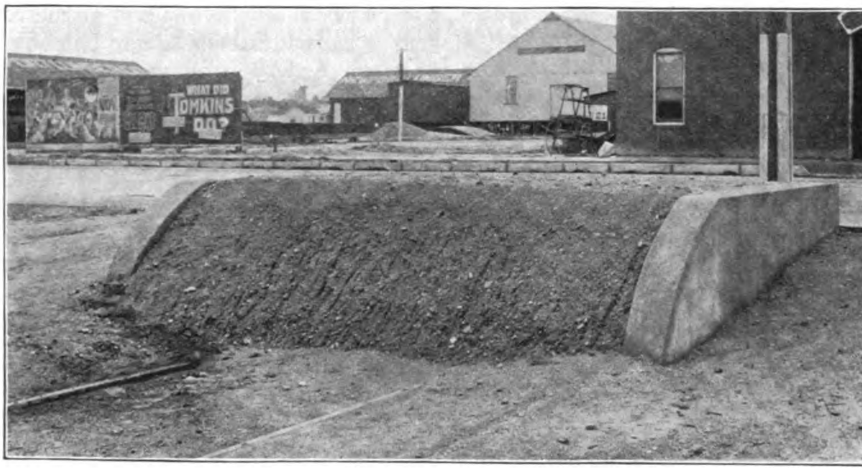


Fig. 461.—Earth Car Stop, Southern Pacific Co.

bed of cross ties laid touching side by side, and on these ties there are two guard rails about 5½ ft. apart, or just far enough outside the line of the traffic rails to let the wheels drop off at the end. When a car is pushed off the end of the track the wheels go bumping over the ties for a distance of 30 ft. before reaching the dirt heap, and the guard rails prevent the truck from slewing; they also serve to hold it in line when the car is being hauled on the stub ends of the rails again. On some roads a large stick of timber is set in the ground at the end of the track, for a bumping post, and the back side of this post is planked up to retain a long heap of earth thrown up as a backing for the post.

Ordinary wheel stops or chocks are not supposed to be hit hard, and are used only as a sort of reminder that the end of the track is there. One form is a casting bolted or clamped to the rail head. In another form the ends of the last rails of the spur are bent upward for a foot or so at about the same curve as the wheel tread; in another, the ends of the rails are bent upward squarely and a 12x12-in. stick of timber is put across in front of the bent-up ends and bolted down to the rails with U-bolts, for the wheels to strike against. In still another style the end of each rail is curved upward 12 or 15 ins. high and backed by a stick of timber or braced piece footing into a longitudinal timber under the ties. A very simple wheel stop is made by laying a piece of 6x8-in. timber across the rails and backing it up by two posts driven or set in the ground, at either side of the track, the top of the posts projecting out of the ground just high enough to hold the cross timber. In order to prevent the timber from being carried away it is chained to the posts.

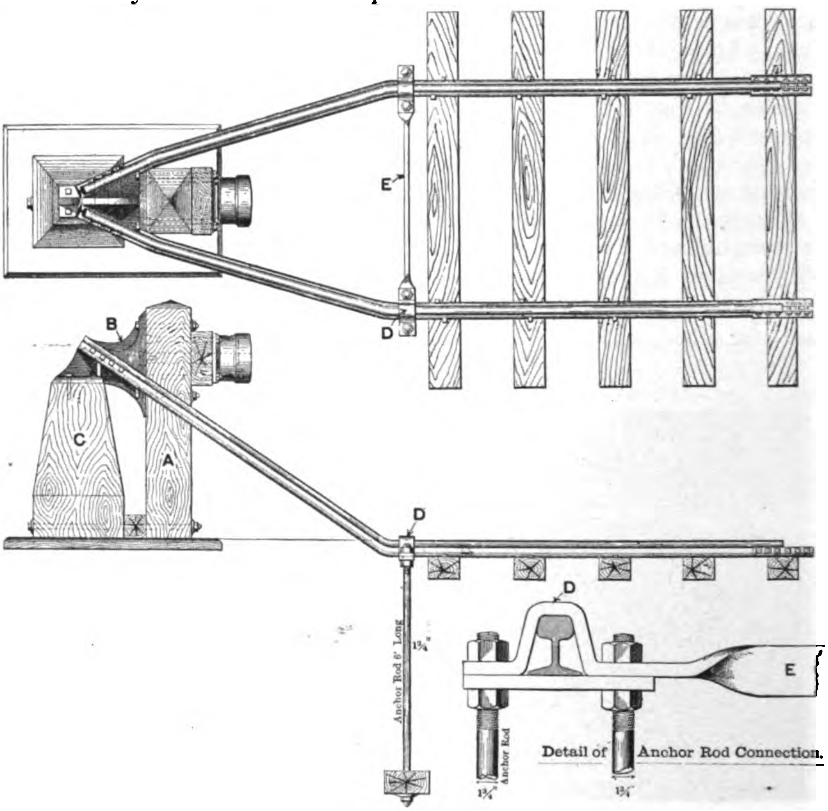


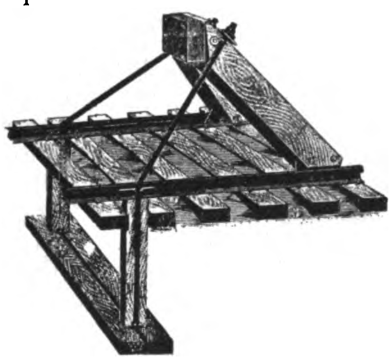
Fig. 462.—Ellis Bumping Post.

About the simplest form of bumping post is a heavy vertical post set in the track and braced at the back with a stick of timber. A contrivance of this kind is sometimes made by setting a bunch of ties, two wide and two deep, in the ground about 4 ft., and bracing them with two leaning ties footed against a tie placed crosswise to them in the ground. It goes without saying that such a piece of construction will not stand a very heavy jar, and in reality it is only an excuse for a bumping post. A very substantial bumping post is made by driving a group of piles into the ground at the end of the track, to serve as a backing for the buffer block. Tough oak piles are hard to break off, and, being somewhat springy, are hard to knock out in ordinary usage. In bumping posts of this style in service on the Pittsburg, Ft. Wayne & Chicago Ry., four piles are used. The piles are driven two abreast, in two rows about a foot apart, with a stick of 12x12-in. timber between the two rows at the hight of the buffer block, the whole being bolted through and through.

An improved bumper of the "framed" type is made by framing the post into the middle of a heavy longitudinal sill, buried about 2 ft. under the track. The vertical post is secured against being lifted off the sill by a heavy strap passing under the sill, and, in addition to a leaning timber at the back of the post, footing into the sill and serving as a brace, there is a heavy bolt or stay rod passed through the brace timber just in rear of the vertical post, thus holding the brace timber down to the sill. More commonly a pair of such frames is used, being placed parallel and about 2 ft. apart, center to center. A cross timber is placed in front of the two vertical posts for a buffer block or deadwood support, and the buffer block is sometimes backed by a set of car springs and faced with heavy steel plate. The sills abut against a cross timber buried in the ground to serve as a backing piece. The sills are usually made of 12x12-in. timber, the vertical post of 12x16-in. timber and the brace piece of 12x16-in. timber. Bumping posts of framed timbers are somewhat expensive and, of course, rot out quite rapidly. Although they were formerly in service on a large number of roads bumping posts made so largely of timber are gradually going out of use.

The type of bumping post which now seems to meet with most favor is some form of construction which is anchored to the track rails, so that a blow against the post is largely transmitted to the rails in a manner to put them in tensile stress. The different styles of posts designed on this principle are almost too numerous to mention. The original post of this type and one of the simplest, and perhaps best known, is the Ellis bumping post, shown as Fig. 462. A heavy oak post (*A*) is set in the ground, or stood upon a plank platform resting upon masonry or a bed of ties, and this post is secured in an upright position by bending both track rails upward at an angle of about 35 deg. and inward, so as to embrace the post at about the hight of the buffer block. A heavy casting *B*, resting upon the top of another post *C*, serves as a backing for the stop post *A*, directly behind the buffer block. Both rails are securely bolted to this casting by large bolts which pass through all three. A strut *E* with clamps *D* is placed between the rails at the point where they bend upward, so as to prevent them from being drawn together when under tensile stress. At the same point the rails are held down by anchor rods secured to a buried timber, which, in addition to the weight of the car, makes the rails quite secure against being lifted. In applying this bumping post to a trestle the anchor rods are secured to the track stringers. The bumping post shown has a spring buffer and is for passenger cars. The post for freight cars has simply the buffer block or deadwood faced with a heavy striking plate. The end rails of the track which bend up around an Ellis post should be full length, so as to put the splices as far back as possible. With short end rails these splices or the bolts in the same are liable to break and let the joint pull apart when a car strikes the post. As used at some points on the Chicago, Rock Island & Pacific Ry. the splice at the joint with each bent end rail and at the next joint back— that is, at the last two joints on each side of the track—is reinforced by pieces of rail 6 ft. long used as splice bars. They are placed outside the ordinary 6-bolt splice bars and bolted to the rail at each end by three ⅞-in. bolts through filler blocks. An interesting application of this bumping post is where a stub track runs against a wall, like the wall of a building, and it is desired to save every possible foot of space. In a case of this kind the stop post (*A*) is cut short and stood in an opening in the wall, and the block which supports the back casting (*C*) is placed on the other side of the wall. This arrangement brings the striking face of the post even with the face of the wall.

A bumping post in extensive use on the Baltimore & Ohio R. R., known as the "Triangular" post, is formed by bending both track rails straight up at an angle of about 45 deg., so as to form a backing for a heavy stick of timber placed crosswise the track at the hight of a drawbar. The backs of the rails so bent up are braced by short pieces of rail bent at about the same slant and footing into timbers running longitudinally under the track and extending in rear of the bumping post. At the point where each track rail turns upward it is anchored to the longitudinal timber underneath, and a timber is placed across the rails to serve as a wheel stop. In other forms of bumping posts of the general type now being considered the track rails are not disturbed. The simplest form of bumping post employing this feature is had by setting a heavy post in the ground and staying its top by heavy rods bolted to the webs of the rails some 7 or 8 ft. in advance of the post. At the upper end the rods engage with a heavy plate which backs up the post. In some cases the buffer consists of a block backed up by rubber or car springs and in other cases it consists of a swing post hinged to the main post at the ground and backed by springs at the top. A bumping post that is extensively used on the Grand Trunk Ry. has an oak post standing on each rail, with a cross beam between the two at proper hight for the buffer. The center of this beam is braced by three diverging oak struts footing against a timber laid across the rails in rear of the upright posts. The foot of each upright post supporting the bumper beam, and each end of the cross timber on the rails, is backed by a casting clamped to the rail.



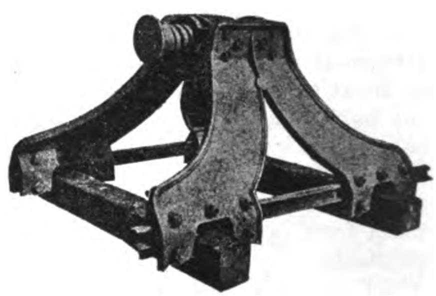


Fig. 463.—Economy Bumping Post. Fig. 464.—Haley Bumping Post.

The most numerous class of bumping posts are anchored to the rails by some form of tie rods, in front, and braced at the back by struts footing into the rails by some bolted or clamped connection. The Economy, the Fairbanks-Morse and Gibralter bumpers are of this description. The Economy bumper, in use on the Chicago, Milwaukee & St. Paul Ry., is shown as Fig. 463. Two heavy oak struts are bolted at their base to the track rails and brought together at their upper ends against the back of the buffer block. These strut timbers stand at an inclination of about 45 deg. and are secured in position by heavy tie rods anchored to ties or long timbers buried up beneath the track. Between the anchor timbers and the rails there are timber struts which serve to utilize the weight of the track and the load upon it to prevent the lifting of the anchored timbers. At the points where the tie rods straddle the rails there are cast bearing pieces bolted to the rail, with lugs in position to prevent the straightening out of the tie rods. The Fairbanks-Morse bumping post consists of a 12x12-in. post set deeply in the ground, in the middle of the track, and through bolted between two ties spaced 10 ins. apart and let into the post 1 in. on each side, this post being anchored to the rails in front and braced to them at the back. The anchor rods are 1¼x4-in. iron straps bolted to the web of the rail on the outside and passed back of the post. The back braces consist of two pieces of old rail bent up to bear against the back of the post at the top and bent at their feet to bolt against the track rails through filler blocks. At the feet of the back braces there is a stub switch rod to prevent the rails from being spread apart by outward pressure from the back braces, and there is another switch rod on the rails at the anchor rod connection, to act as a strut and hold the rails against being pulled together. The buffer consists of a set of ordinary car springs backed by the post and faced with a heavy striking plate. The Gibraltar bumping post consists of a bumping head backed by two brace rails running straight back and inclined at an angle of 45 deg. with the horizontal. These brace rails run down to a base plate, to which they are riveted, to make connection with the end rails of the track, which are bent inward and riveted to the same base plate, which lies on a tie in the center of the track. To prevent the bumping head from rising when it is struck there is a heavy U-bolt passing through the head and secured to a long piece of inverted rail laid under the ties. This inverted rail extends from underneath the base plate, in the rear, to a point in advance of the position of a car truck when the car is run up to the post. To hold the bumping head central there are two stay rods anchored to the rails in advance of the bumper head. The Cox bumping post, designed by Mr. J. B. Cox, chief engineer of the Chicago Junction Ry., is built slightly out of center with the track, to bring the center line

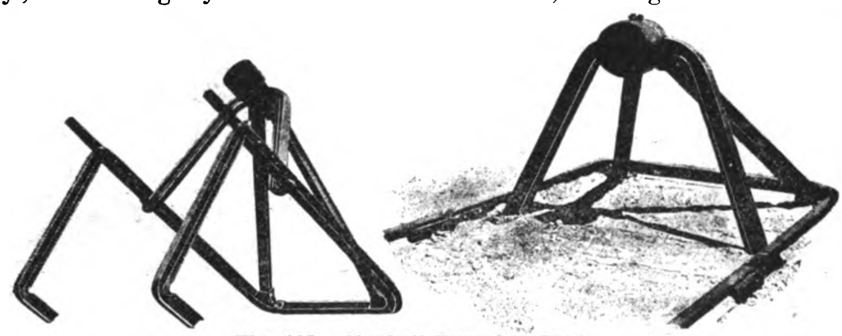


Fig. 465.—Haskell Bumping Post.

of the post to coincide with the striking part of the M. C. B. coupler head, which is not central with the track. The post is a 15-in. I-beam with web transverse to the track, standing upon a base plate which is placed upon a tie, and 1¾-in. anchor rods run down to a cross timber buried 6 ft. below the rail, as in Fig. 463. At the point where the anchor rods pass vertically downward they are attached to the webs of the rails, on the outside, as in Fig. 463, and at this point the rails are cross-tied by a 4x6-in. angle iron strut. The striking plate stands even with this strut and is backed against the post by a 12x12-in. oak timber 3 ft. long supported upon angle iron braces footing into the angle iron cross tie. The track cross ties rest upon a set of longitudinal timbers, and under these there is blocking running down upon the anchor timber to prevent it from being pulled up by stress on the anchor rods.

The Haley bumping post (Fig. 464) is made entirely of metal and consists essentially of two heavy, flanged A-frames with their feet bolted to the track rails and the tops inclined together and carrying a coiled spring buffer. The legs of the frame are of cast steel, the feet straddle the ties and are shaped to fit the contour of the rails. A similarly shaped clamping plate is placed on the inner side of the rail and secured to the main frame by means of three bolts above the rail and two beneath. Attached to the lower bolts in the forward legs there are anchor rods secured to a piece of rail buried beneath a bed of ties 4 or 5 ft. under the track. Between the tops of the side frames there are two transverse webs, through which the buffer rod or plunger passes. The buffer acts against two double coiled springs, one being placed back of the buffer head and the other between the transverse webs. The space between the side frames permits the pilot of an engine to pass between them, so that the pilot drawhead may engage with the buffer. The plunger is set off the center of the post, so as to receive a straight blow from coupler knuckles. The Haskell bumping post, devised by Mr. B. Haskell, superintendent of motive power of the Pere Marquette R. R., is made principally of old rails and is bolted to the end of the track rails, as shown in Fig. 465. A single rail is bent into a loop, for a base, the rear corners of which support the diverging braces of the buffer. The front ends of the base rail are turned downward into the earth and the extreme ends are bent up to engage an anchor timber. The buffer consists of a pocket and cap holding the buffing springs.

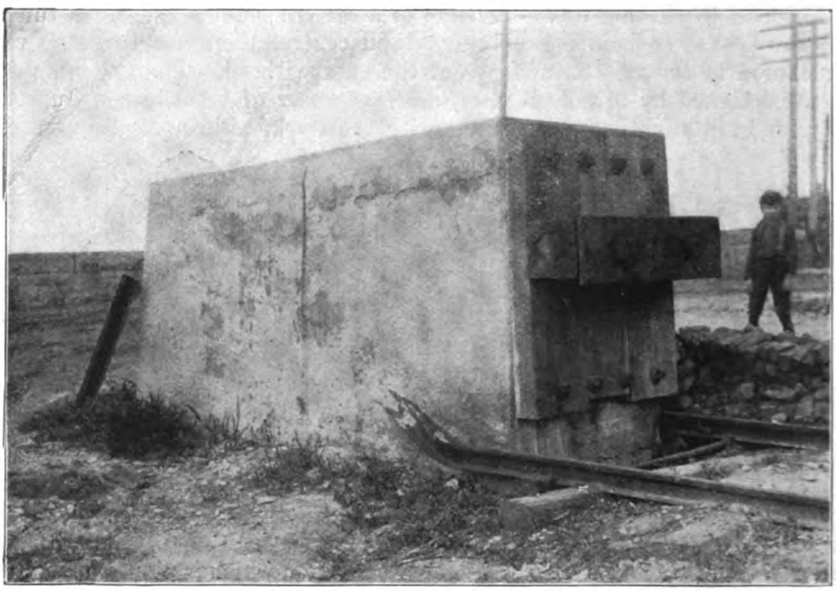


Fig. 466.—Concrete Bumping Post, C., R. I. & P. Ry.

At the ends of stub tracks in the freight yard of the Chicago, Rock Island & Pacific Ry., between Forty-second and Forty-third streets, Chicago, there are some bumping posts of monolithic concrete masonry. Essentially, each bumping post consists of a concrete pier 10 ft. long, 4½ ft. wide, at the deadwood, and 9 ft. deep, reaching 4 ft. below the surface of the ground. The sides of the pier have a slight batter. Just in front of the pier the rails are united by a switch rod. The pier is faced with 4-in. planks standing vertically and bolted to the masonry, so that the shock from cars is distributed over the whole surface. The deadwood consists of an oak timber faced with iron plate and bolted to the pier through the facing plank with two large bolts. Each rear corner of the pier is protected against damage from wagon wheels by a fender consisting of a piece of rail standing in the ground and leaning toward the pier. Respecting the rail connection with the pier there are three different plans. In one style the rails stop short and are in no way connected with the concrete mass. In another style the track rails extend into the pier, being bent inward on the level of the track to meet in the interior of the mass of concrete. In the third style of construction (Fig. 466) the track rails straddle the front end of the pier and are bent both inward and upward, like the rails of an Ellis bumping post, running into the concrete until they nearly meet, where they are held together by cross rods, so as to take firm hold of the pier. These "posts" cost $50 each, complete in place (which was $25 less than the purchase price and cost of erecting approvable posts of patented designs then on the market), and those to which the rails are attached have given satisfactory service. The one built independent of the rails rises at the front end when bumped hard, and the dirt jarred under it must be dug out occasionally to let it down. The one with the rails bent inward but not upward has stood well. One of those built with the rails bent both inward and upward withstood the shock of a 25-car train thrown against it so hard that a car-load of large dimension stones was unloaded over the top of the pier and the car broken in two and doubled up. The pier was cracked diagonally from bottom to top, following the line of the bent-up rails, but was not moved out of serviceable position.

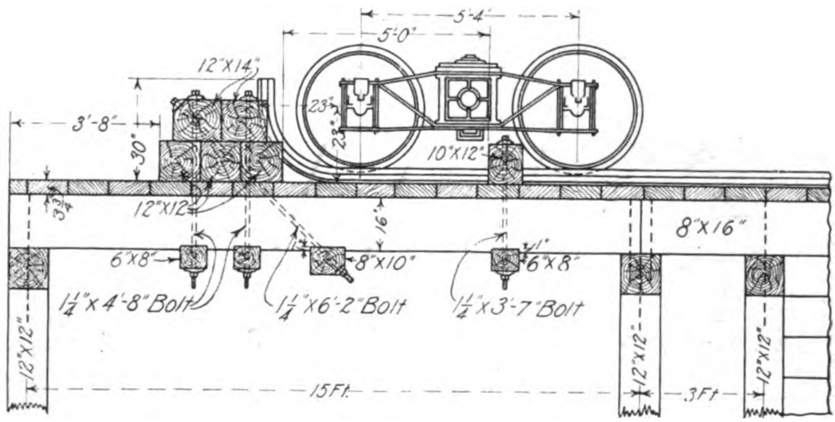


Fig. 467.—Standard Bumper for Ore Docks, Duluth & Iron Range R. R.

For absorbing the shock of striking cars, so that the full force will not act suddenly on the post, rubber springs and spiral springs are employed, as already explained. What is perhaps the most complete arrangement of this kind is the Webb hydraulic buffer, used on the London & Northwestern Ry., in England. This consists of a pair of braced posts backing up hydraulic cushion cylinders or dashpots which bring the striking car to rest without recoil. Each of the two buffer heads is backed by a piston working within a 9-in. cylinder 2 ft. long perforated with thirty ¼-in. holes and enclosed by an outer tight casing with a 1¼-in. annular space between them. Connecting with this annular space there is a vessel or well partially filled with a mixture of petroleum, soap and water, which is forced up into the annular space and inner cylinder by air pressure at 45 lbs., whenever the buffer is in normal position. As the piston is pushed in, the liquid escapes from the inner cylinder into the annular space and into the well against the air pressure, but with constantly increasing resistance, owing to the diminishing number of escape holes ahead of the piston. Under constant use the full pressure can be maintained about six months without attention. When the pressure decreases it is restored by means of a hand pump.

Not every type of bumping post in extensive use is applicable to track on trestles or other elevated structures, and hence there are a number of special designs for such service. Figure 467 shows the plans of a standard bumper in use on ore docks of the Duluth & Iron Range R. R. The bumper proper consists of five heavy timbers in two layers—three 12x12-in. pieces in the bottom and two 12x14-in. pieces in the top layer—placed crosswise the stringers and anchored to the same with long bolts and brace rods. Against these timbers the rails are curved upward to a radius of 23 ins., and just in advance of them a 10x12-in. timber chock, on edge, is notched over each rail and bolted fast to the stringers. This chock serves to stop the car or to retard its motion when jumped by the leading pair of wheels, and it is placed at such a distance from the bumper proper that the second pair of wheels meets the chock at about the same time that the leading pair meets the bumper. The bumper and chock timbers extend continuously across the double track running over the ore pockets.

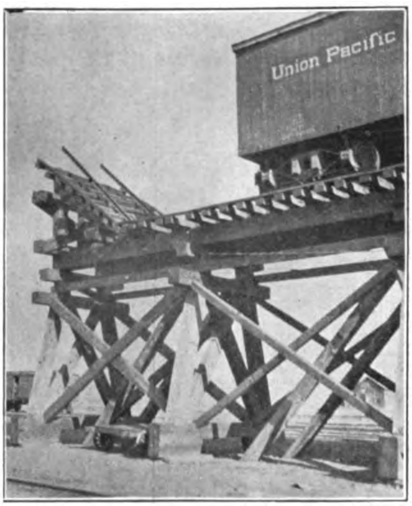


Fig. 468.—Car Stop on Trestle, Union Pacific R. R.

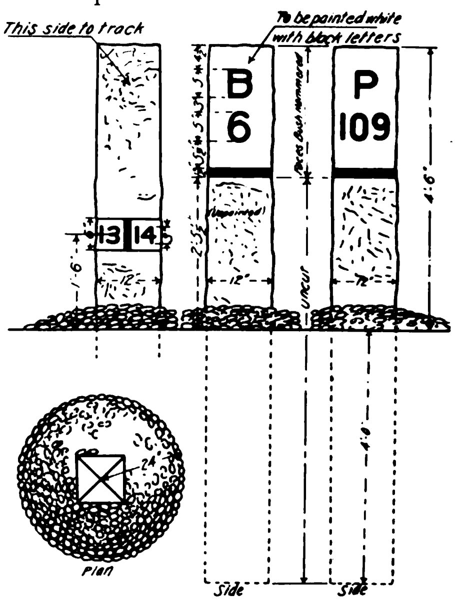


Fig. 469.—Granite Mile Post, Boston & Maine R. R.

Figure 468 shows a form of car stop used on trestles of coaling stations at several places on the Union Pacific R. R. The end of the track is upturned at an angle of about 45 deg. and supported by a timber framing at the back. This backing consists of a low bent, on which are laid leaning stringers to support the track, the bent being stayed by long bolts running forward to the cap of the second trestle bent from the end, and from this cap long bolts are run to the cap of the third trestle bent. The ground bents near the end of the trestle are then braced together and also by leaning timbers run to the ground. The leaning stringers are notched over a cross beam securely bolted to the horizontal track stringers. This short and steep incline is supposed to be sufficient to stop a car running against it at any speed to be expected in such a place. The bumping post for the end of coaling trestles on the Southern Ry. is braced up from the ground by long timbers, to relieve the trestle of longitudinal stress when the bumper is struck by cars.

158. Sign Boards.—Sign boards and sign posts should be arranged according to some system. Those used for different purposes should vary distinctly in shape, so that a glance at one, even after dark, will instantly reveal what it stands for. Thus, for example, the board or panel on a post used for one purpose might be round; that for another, square or rectangular; another, diamond-shaped, and so on. Everything should be plain and distinct, without attempt at ornamentation, and the signs should be worded as briefly as may be consistent with properly conveying the meaning. Running signs should be placed near the track, no part being nearer the rail than 7 ft., however. The minimum distance on some roads is 10 ft. from the rail. Where two or more would come at about the same place they should be moved a little way apart, keeping within limits prescribed by law for the locality. The posts should always be long enough to set firmly in the ground. In districts where the snowfall is deep the hight of the post above the ground must be governed somewhat accordingly. Brush should at all times be kept clear of sign boards and clear of the ground over which it is necessary to look in order to see the sign from the trains at the proper distance.

Mile posts are usually 10x10 ins.x8 or 9 ft., set 3 ft. in the ground. They are usually painted white, with the numbers put on plainly, in black, and sometimes also the initial of the city or terminal point from which the distance is reckoned. The distances from two terminals are sometimes placed on the same mile post, but usually on opposite sides, and each on that side which faces in the direction of the place; so that one looking ahead from a train will see the distance to the point from which he is traveling. In cases, however, the two distances are placed on adjacent sides of the post and the post is turned cornerwise to the direction of the track, so that both inscriptions may be seen simultaneously, as one approaches the post. The Grand Trunk Ry. has mile posts of triangular section, set with the back side parallel with the track. The distances to the terminals are painted on the two faces of the post which stand oblique to the track. This arrangement is convenient for passengers. The top of the post is sharpened, to shed rain. If more than one distance is given on the same mile post the initial of the place should appear with each distance. It is, however, a matter of some convenience to mark on each mile post the distance to the nearest station, in both directions, in which case, to avoid confusion with the terminals, the initial of the station should be omitted and the number indicating the distance should be in small figures placed low-down on the post, and on the side of the post facing from the station. The Michigan Central R. R. uses minor posts set at the half-mile and quarter-mile points.

In line with permanent or more durable construction, stone mile posts are used quite extensively, being in some cases a stone of square cross section, and in other cases a slab, roughly dressed, with smoothly dressed faces for lettering. The Lehigh Valley R. R. uses a flagstone 20 ins. wide, 3½ ins. thick, and 6½ ft. long, set 3 ft. in the ground. A 16-in. patch at the top is painted white, with black letters, and the remainder of the post is painted black. The stone mile post of the Boston & Maine R. R. is of granite, 12 ins. square in section, 8½ ft. long, set 4 ft. in the ground. The side faces, occupying 24½ ins. of the top part of the post, are bush-hammered, while the remaining surface of the post is uncut. Distances are painted on the post with black letters and figures 5 ins. high on a white field. On mile posts which divide sections there is a face 6 ins. high, 1½ ft. from the ground, on the side toward the track, with painted figures 3 ins. high. Thus, the post shown as Fig. 469 is 6 miles from Boston and 109 miles from Portland, and stands on the dividing line between Sections 13 and 14. The post at the ground line is kept free from grass and other vegetable growth by a heap of cobble stones 4 ft. in diameter.

The Chicago & Eastern Illinois R. R. is using mile posts made of concrete. These posts are 8x8 ins. x8 ft. long, set 3½ ft. in the ground. The concrete mixture consists of 1 part cement, 1 part sand and 2 parts of crushed stone. Near the top of the post there is a letter panel 14 ins. high, molded black, being colored with lampblack mixed in with the concrete, which is separated from the other concrete by strips of wood placed in the molding form. The letters and figures are molded in on this black panel, and after the concrete has set they are painted white. The weight of each post is 498 lbs., and the total cost, including labor and materials, is 82 cents.

Iron, in the shape of old boiler flues, is used a good deal for sign posts, including mile posts. On part of the Lehigh Valley R. R. system the mile posts are made by riveting a piece of old boiler plate 15 ins. square to the flattened end of an old boiler tube 8 ft. long set 3 ft. in the ground. The plate is fastened to the tube at one corner, so that its diagonals stand vertical and horizontal. The lower part of the tube is fastened with staples to a piece of tie 3 ft. long, standing vertically at the side of the tube and buried, to give the post stability in the ground. On some roads the mileage is marked on boards nailed to the telegraph poles. Such is the system on the Southern Pacific road, where the "mile boards" are nailed to the nearest telegraph pole, 10 ft. above ground and facing the track. On the Atchison, Topeka & Santa Fe Ry. the exact mile points are marked by posts 4 ins. square driven into the ground just outside the ends of the ties. The number of the mile is painted on the post and also in large figures upon a steel plate that is fastened to the nearest telegraph pole. As these wooden posts need renewing they are replaced by a piece of old boiler flue 3 ft. 10 ins. long set 2½ ft. in the ground. The top part of the flue for a length of 12 ins. is flattened together and figures ¾ in. high are stamped into the metal fully $^{1}/_{16}$ in. deep. Curve posts are made of the same material, the same size and marked in the same way. Above the ground line these posts are painted white.

Whistling posts for stations are usually marked "W" and "S," one above the other, and the post is placed ½ mile or one mile from the station; in other instances a station whistle board is used, having the name of the station painted thereon. Whistling posts for highway crossings, marked "W" and "X," are usually placed ¼ mile from the crossing, the distance being fixed by state law. Whistling posts are set on the engineer's side and ring posts (marked "R") usually on the fireman's side, at some distance from the crossing required by law—usually ¼ mile. The most ordinary style of whistle post is shown in Figure 276. On the Southern Ry. the standard whistle post for highway crossings is a cast iron post of +-shaped section, flattening into a plate at the top. The post is painted white, with two long cross bars and two short ones, in black, on the plate, to represent the whistle signal, thus: —— —— — —, reading down the post. Figure 551 shows a wooden post painted in this manner.

A convenient sign for the public at highway crossings consists of two crossed boards having the words "Railroad Crossing" on one board, and "Look Out for Cars" on the other. An open frame-work of diamond shape, with these words distributed around the four sides, is also a very common form of sign for highway crossings. On the Lake Shore & Michigan Southern Ry. the highway crossing sign board consists of a diamond frame of 1x10-in. boards sandwiched between two pieces of 2½x7-in. oak plank, which constitute the post part of the sign. This sign should be set facing the direction of the wagon road, at some conspicuous place near the track, but out of reach of vehicles loaded with bulky things like hay, etc. The usual distance from the track is 15 to 25 ft. Both sides of the board are lettered, so that, ordinarily, one sign board serves for both directions. Where there are a number of tracks at the crossing or wherever one board cannot be seen to good advantage from both directions, there should then be a sign on both sides of the track; in which case the lettering can be omitted from the track side of each board. Another warning that is placed on the crossing sign boards of some roads is: "Danger! Stop, Look and Listen."

Other sign boards in ordinary use along the track not already mentioned in connection with previous subjects, are "Stop," "Slow" (generally used in connection with every "Stop" sign), "Yard Limit," "Dump Ashes," "Water Tank. . . Mile Ahead," section limit posts, warning signs for private crossings; sign boards to mark the limits of towns and cities, county and state boundary lines, right-of-way boundaries; bridge number signs, flanger boards, rail record posts, rail monuments for marking the ownership of tracks, "No Thoroughfare" and "Do Not Trespass" signs; and station signs at points where there is no depot, such usually being lettered on both sides and placed at right angles to the track. A common form of board for a stop or slow sign is a cast iron plate of oval form $\frac{1}{4}$ or $\frac{3}{8}$ in. thick, bolted to a post. The letters are raised $\frac{1}{8}$ in. and cast integral with the plate, and there is a $\frac{1}{2}$-in. rib at the border. The slow and stop signs of the Pennsylvania R. R. are semaphore arms fixed to posts, the arm being let into the post and nailed fast. The slow board has the conventional fish-tail end and is painted green, with white letters; the stop board is painted red, with white letters. The stop sign at a drawbridge is usually placed 200 ft. from the end of the span, and at railroad crossings or junction points, 400 ft. from the crossing, the exact distance, however, being generally, regulated by law. In addition there is usually a slow board or cautionary sign placed one mile from the crossing, junction or drawbridge, lettered "R. R. Crossing One Mile," the word "Junction" or "Drawbridge" being substituted as the case may require. Slow and stop boards carry lanterns or lamps at night, the color corresponding, of course, to the signification of the sign.

Right-of-way boundary posts are frequently made by cutting up the sound portions of old telegraph poles, painting white and setting every 500 ft. along the line, or at more frequent intervals, in case there are jogs or corners in the line. As permanency is one of the principal requirements of such posts a piece of rail is undoubtedly more suitable for the purpose, and such is in use on some roads. The Cincinnati, New Orleans & Texas Pacific Ry. has a short post with a circular cast iron plate painted black, with letters and figures stenciled in white, to give the location, name of manufacturer and the age of rails. The Chicago, Burlington & Quincy Ry. uses a rail monument for marking the ownership of tracks. The piece of rail is 4 ft. long, set 3 ft. in the ground, with the name of the company owning the tracks stamped in the head and base of the rail. A "Close Sand Valve" post is sometimes placed 200 ft. from interlocking switches or detector bars, to protect such apparatus from sand.

On some roads it is the practice to number the curves, beginning at one end of each division. On the Buffalo, Rochester & Pittsburg Ry. a triangular sign board is placed on a telegraph pole at each curve, giving the number of the curve and its degree of curvature. It is usual to put the number and degree of curve on stakes or monuments opposite the beginning and ending of every curve; and if the curve is spiraled, the number of the curve is placed on stakes where the spiral joins the tangent, and stakes showing both the number of the curve and the degree of curvature are placed at the ends of the circular curve; on compound curves, curve posts are placed at each point where the curvature changes—i. e., at each P. C. C. Such posts or stakes are usually set at the edge of the ballast, on the shoulder. The amount of superelevation for the curve, when marked at the curve, is usually placed on the back side of the stakes showing the number of the curve and the degree. On double track, where the two tracks have different elevations, elevation stakes are set outside each track; otherwise, one set of stakes outside the outer track is usually sufficient. On some roads a stake marked "E 0" (Elevation zero) is placed at the point on tangent where the elevation runs out, and another stake marked with the full elevation, as "E 4," is placed where full elevation is to be given. The numbers on wooden curve stakes or posts are frequently burned in with metal dies. The Southern Pacific Co. uses creosoted stakes. Curve monuments are treated in Chapter V, § 48, but it may be well enough to repeat here that a post that is very commonly used for this purpose is a piece of rail about 5 ft. long split up the web at the bottom and having the two parts bent outward to resist pulling up.

The prevailing colors for sign boards are a white ground with black letters, with a black border, if a border is used. Occasionally, however, the ground is made black with white letters; and to obtain distinctness without changing the shape of the board it is sometimes the practice to use white letters on a red or green background. The shape of sign boards and the details of design, such as the hight of post, the size of board or panel, the method of attaching the board to the post, etc., vary somewhat on different roads, but it is hardly worth while to go into particulars. The Cincinnati, New Orleans & Texas Pacific Ry. is one of the roads on which the sign boards for the various purposes vary quite widely in design. On the other hand, the Chicago, Burlington & Quincy Ry. might be cited as one of the roads on which the designs of the various standard track signs vary but little. The highway crossing whistle, station whistle, flanger, sand valve, derail, section, rail record, and clearance signs of this road are peeled cedar posts without boards or panels, with black lettering on a white patch near the top of the post. All sign boards or panels are rectangular in form, with the exception of the highway crossing sign, which has crossed pine boards, 6 ft. 2¼ ins. long, 10 ins. wide and 1¾ ins. thick, gained into opposite sides of a 16-ft. peeled cedar post set 4 ft. in the ground, the tips of the crossed boards, which stand at an angle of about 30 deg. with the horizontal, coming even with the top of the post. The boards are painted white on both sides, with black letters 8 ins. high, one board reading "Railroad" and the other "Crossing," while the post is faced on two sides and painted white with black letters, "Look Out for the Cars," reading down the post. The state line post is oak, 8x8 ins. x9 ft., set 3 ft. in the ground and painted white with black letters. The mile post is oak, 6x8 ins. x12 ft. long, set 4½ ft. in the ground and placed on the "right-hand side of the track looking from Mile Post 1." In locations where there is not sufficient room for a horizontal sign the stop and slow signs are painted on peeled cedar posts without boards or panels. In nearly every case the post and back of sign are painted with mineral paint and the signs are painted white, with black letters. All running signs are placed on the right-hand side of the track, and all other signs except mile posts are placed on the north or west side. The nearest point on any sign must not be nearer the rail than 7 ft.

On the Nashville, Chattanooga & St. Louis and the Pittsburg, Ft. Wayne & Chicago roads every fifth telegraph pole is numbered, for convenience of locating the bridges and other structures more closely than can be done with mile posts. The system also serves as a convenient means for locating defective places in the track, the scenes of accidents, the starting and ending points of new rail laid, etc. The section foremen in making their reports use the pole numbers to locate the places where work is done. The numbering starts at the division points. The Lehigh Valley and some other roads also have in practice the system of numbering the telegraph poles. Mail cranes, bridge signs, telltales or bridge warnings and station signs are customarily looked after by the bridge and buildings department, and signal posts and sign boards used in connection with interlocking switches and signals by the signal department.

Sign boards and posts should be maintained in a plumb position. A post which has become leaned over naturally appears like something which has gone out of use. As soon as the use for a sign board or post has ceased it should be removed: along a railroad there should be no signs posted which have no significance. A coat of fresh paint occasionally adds to the impressiveness of a sign; and a pile of cobble stones or rock ballast placed around the post, where it enters the ground, will protect it from fire and from decay which starts from contact with vegetable growth. The matter of keeping sign boards brightly painted is of considerable importance, and the expense is no small item. To a small extent enameled steel signs are being used. The enameling is done in the colors desired, and on either sheet or plate metal or cast iron. It is said that such signs or signals will stand for many years without rusting or tarnishing, the only care required being to wipe the dust off them occasionally. The conspicuousness of sign boards invites target practice, and in localities where huntsmen are numerous wooden signs soon become shattered by gun shots. In such places it is expedient to use sign boards of boiler plate or cast iron, the letters being stenciled on, in the former case, and raised and cast in with the plate in the latter, if the reading of the sign is to be permanent. Wooden panels may be kept from splitting by nailing battens at the back with clinched nails.

As a means of prolonging decay in wooden posts or telegraph poles it is quite largely the practice to dip the portion of the post which is to set in the ground, into hot coal tar or pitch. It is well known that the part of the post which decays first and most rapidly is a narrow ring at the ground line. A recently devised means of protecting timber against decay at this point is to encircle the post with a length of sewer pipe 2 or 3 ins. larger in diameter than the post and have it project about 2 ins. above the ground line. The space between the pipe casing and the post is then filled with asphalt or clean gravel and tar or pitch poured in hot, so as to fill any checks or seasoning cracks in the post. The space thus filled forms a water-tight packing around the post. In setting new poles or posts a solid section of pipe can be used, by slipping it over the end of the pole, but for poles already set a section of pipe in two parts is provided, the edges of the two parts being tongued and grooved, so as to fit tightly together and make a good joint. The tops of sign posts should be pointed or slanted, so as to shed water. As a means of resisting fire and decay iron posts are coming into use to a considerable extent, as already stated in some particular. Old boiler tubes, painted with some kind of preservative coating, are used for posts, and the sign is painted on a cast plate or sheet metal target riveted to the post. The Mathews post, in use on the Pennsylvania, the Missouri Pacific, the Wabash and other roads, consists of a steel T-bar secured to a length of sewer pipe by braces and a collar on the pipe, and set in the ground. The piece of pipe is filled with concrete or tamped with earth, as in the case with fence posts of similar construction, shown in Fig. 427. The standard track signs of the New York Central & Hudson River R. R. have posts of old rails and panels of $^3/_{16}$-in. steel plate. For a hight of 4 ft. above ground the post is painted black, and above that white. The posts for various signs are 12 to 15 ft. long, of which $4\frac{1}{2}$ to 5 ft. is set in the ground Around each post there is a cobble stone paving 5 ins. high and 2 to 3 ft. in diameter.

159. Signals.—Section foremen should understand thoroughly the established system of flag, lantern, hand, torpedo and whistle signals on their road for the operation of trains. Red flags and torpedoes should be carried on the hand car at all times, and during short days in winter a red lantern also. The flags should be attached to short sticks and, to keep them dry and clean, they should be carried in a galvanized sheet iron tube or in a box arranged upon or under the hand car. Torpedoes must be kept dry, and may best be carried in a tin can having a tight cover; a baking-powder box is the thing. The schedule of the trains, both passenger and freight, should be thoroughly learned, particularly so far as pertains to the time when each train is due on the section or at the first station in the direction from which the train approaches. Foremen should carry reliable watches, which they should frequently compare with the standard time of the company, as kept in telegraph stations or as carried by trainmen. If the foreman starts out at or passes a telegraph station at any time during the day he should get from the operator information regarding any irregularity in the running of the scheduled trains or what irregular trains are running, if any, and about what time he may expect them. It is also well to know in advance the number of sections boarded for each train.

Trackmen should never take up a rail or engage in any work which would be equally as dangerous to the passage of trains, without first putting out flagmen or red flags in both directions, if on single track, or against trains running on the track affected, in case of double track. The question of sending flagmen both ways for one track of a double-track road is usually covered by the rules of the company. "Anything that interferes with the safe passage of trains at full speed is an obstruction, and must not be undertaken without proper protection," is a rule generally followed. Loaded push cars on main track are considered obstructions to be protected by danger signals, although on some roads the rules permit their use in day time where there is a tangent of at least ½ mile, without signals. As the engineers of special trains are supposed to be looking out for such things permission of this kind is not inconsistent with good practice, but loaded push cars should not be used at night, or run around curves or be allowed to stand upon them, where the view is obstructed, without signal protection. No blasting should be done near the track without first sending stop signals in both directions. In doing work which disturbs or obstructs the track it should always be taken for granted that a train will come before the work is completed, and unless the rules of the company state differently, the danger signal should be sent three-quarters of a mile, which distance would be measured by counting 24 telegraph poles or 132 rails of 30 ft. length. If the train must approach over a down grade the flagman should go farther; if over an up grade of one per cent. or more, a quarter of a mile is far enough. If any of these distances bring the signaling point on a curve, and a tangent can be reached by going a little farther, then the flagman should go on as far as the tangent. Except in cases of emergency no work that will obstruct the track should be undertaken during heavy fogs or snow storms.

It is always best, where the force is large enough, to have a man stay with a stop signal until the work is done; but it is very expedient that he should remain, in any case, if the signal cannot be seen from the point where the work is going on, or during stormy, windy or foggy weather, or at night, or where children might be expected to be playing near the signal. The rules of many roads require that a man must always remain with a danger signal. The man who stays out with a danger signal should be instructed to remain at his post and stop all trains; and under no circumstances to leave his post until he is called in; and also to be sure that he recognizes the right party calling him before leaving.

A misunderstanding might arise by mistaking the accidental gesture or yell of some one not purposely intending to call him. Some companies require that flagmen must be sent both ways to guard an obstruction on one track only of a double track, the same as though the road was single track. When it is found necessary to run trains in both directions over one track of a double-track road, and the change is made under such circumstances that it might not be anticipated by the trackmen, if the first few trains sent in the contrary direction are required to run at reduced speed and blow the whistle frequently (as they should do), then under all ordinary circumstances there would be no need of sending flagmen both ways. Trains running in the wrong direction on any track ought to carry red flags or red lanterns in front. Work trains should run on the contrary track as little as possible, and then only from the nearest crossover to the point to be reached. Of course, within yard limits foremen know what to expect; but in any event where the expediency of sending a flagman might be in doubt it would be well to use the torpedo signal.

A "stop" signal is a red flag displayed by day or a red light by night. The mere presence of the signal on or near the track is all that is required, but if there is a man with it, it is best to swing it gently across the track; but any kind of light swung across the track, or a hand, hat, or other object waved violently on the track, by any person, is a signal to stop. The explosion of one torpedo is a signal to stop immediately; the explosion of two torpedoes is a signal to reduce speed immediately and look out for something ahead. When used by itself the stop torpedo signal is placed at the same distance from the danger point as the stop flag or stop lantern signal would be. The torpedo signal of caution (two torpedoes) is sometimes used by trackmen and placed $\frac{1}{4}$ or $\frac{1}{8}$ mile beyond the stop signal, to call the attention of the trainmen before the stop signal is reached. When used by the flagman of a train the caution torpedo signal is not taken up when he is called in, but is allowed to remain, so as to protect the train during the interval elapsing from the time the flagman is called until the train gets started. When used by trackmen the torpedoes should be taken up when the flagman is called in. Torpedoes should be used in addition to flags or lights whenever, by reason of fog, storm or other unfavorable condition, there is a doubt whether the flag or light may be seen, or whenever a stop signal is left without an attendant. But some roads require the use of the torpedo signal in all cases as an extra precaution taken under the supposition that no one on the approaching train might be looking ahead at the critical time. It should be placed at such a distance beyond the flag or lantern, that when exploded, the flag or lantern may be seen from the engine or head end of the train, but not closer than 150 ft. When two torpedoes are used they should be placed 60 ft. apart. Torpedoes for signals should be placed on the engineer's side, as the train approaches, but on third-rail track they should be placed on that rail which is used by trains of either gage. A man left with a stop signal should, at the approach of the train, wave the flag or lantern across the track until answered by whistle. If for any reason a torpedo signal cannot be given, and the flagman cannot draw the attention of any one on the engine, a handful of gravel tossed so as to strike the front of the cab will seldom fail to make known "what's up." Or if there is not time to do this he should try to throw a rock, club, a boot, or anything he can get hold of, through a window of the rear coach or caboose. There are plenty of old railroaders who have been in position to appreciate the force of this monition. A red or stop flag left standing should be placed in the middle of the track, spread out between two sticks quite firmly stuck into the ground, so as to be well displayed; a red lantern, if left alone (which is not good practice), should be placed just outside the rail on the engineer's side. Flagmen sent to stop trains should be instructed not to permit the engineer to proceed until the exact location of the danger point is clearly understood by the latter, so that no misunderstanding may arise in case a second crew should be working between the flagman and the danger point.

In connection with danger signals it may be interesting to mention that some roads have rules forbidding trackmen to wear red shirts as outer garments, as there have been instances where such have been mistaken for stop signals. In the same connection, also, attention may be called to the contingency when trackmen are caught without lantern or torpedoes, after dark, and occasion arises for stopping a train. In such event a switch lamp, if to be had, may be taken down and put into service, or a piece of waste may be lighted and waved on a stick. A red flag pinned around a white lantern will show a red light; and if the lantern at hand is poor and it is feared that it may be put out by being waved, such an arrangement is sometimes resorted to.

A "slow" signal (green flag or lantern) should be set up in a clear space outside the track, on the engineer's side, just far enough away to clear passing trains. A half mile is the usual distance for placing out a slow signal. In connection with a slow signal protecting a point at which no one is working, it is usual to place a white flag or lantern—that is a "clear" signal—to designate the point from which the train may proceed at full speed. At night it is well to use both the flag and the lantern, as then the flag, which, being white, is conspicuous, readily explains what the lantern is for. If a crew starts in to work between a slow signal and the point which the signal is protecting, another slow signal should be placed some little distance away, between this crew and the danger point, to indicate to an approaching train that the danger point is farther along. If a slow signal is to remain at the same point for any considerable length of time it is a good plan to set a post and attach the flag stick to it horizontally, so that the flag may hang downward, free and clear. A track nut tied to each loose corner or a piece of telegraph wire sewed into the edges of the cloth will prevent the furling of the flag by the wind. A simple and convenient flag and lantern holder in portable form may consist of a piece of 1¼-in. gas pipe 5 or 6 ft. long, pointed at one end, for sticking into the ground, and fitted at the other end with an ordinary T-coupling screwed on to hold the flag stick in a horizontal position. A piece of telegraph wire is bent around the "T" and formed into a hook for holding a lantern.

The fusee is a time-interval signal used principally for the protection of trains, at night or during heavy fogs or heavy snow storms. It consists of a pasteboard tube weighted and spiked at the lower end and filled with a slow-burning composition which will maintain ignition in a heavy wind or in snow or in rain. It burns with a brilliant colored light, illuminating the whole region roundabout, and is made to burn out in a definite time—five, ten or fifteen minutes, according to the interval desired. It is stuck into a tie or into the ground and lighted (and sometimes lighted and thrown from a train), and no train is supposed to run by it until it has burned out. An improved form burns a series of colored lights. The first, being red, say, will burn five minutes; the second green or blue, burns five minutes longer; and the third, white, finishes out the remainder of the interval. An engineer following the train from which this fusee has been thrown is thus enabled to tell very nearly the time which has elapsed since the train ahead departed, and may govern his movements accordingly. The fusee may thus be substituted for the cautionary torpedo signal (two torpedoes) left by a flagman to protect his train while he is running in, after being called. Permission should be granted section foremen to carry and use fusees, upon occasion. On crooked roads section crews are sometimes held out on the track until well into the night, waiting for delayed trains and fearing to venture forth with the hand car, especially if there is a bridge to cross. If caught without a lantern it is impracticable to flag the car in, and such a method of running is slow and laborious (for the flagman) at any time. Torpedoes left upon the track in such a case would be in service until exploded and would then needlessly bother the engineer, unless the train came along soon after they were placed. A 10-minute fusee would enable the car to get over a good distance, under protection, and the chances would be that in many or most instances the train would not arrive before the signal had burned out.

Trackmen should never hesitate to stop or slow up a *train of any class,* whenever in their judgment there is danger ahead of it, or about to be; as in the case of a threatening slide, for instance. Some are too timid in this respect; and while flagging a train some trackmen have been known to lose their presence of mind as completely as does an ordinary man when called upon to speak before a public audience. Any engineer or trainman who will abuse a trackman for holding a train, for any reasonable cause, ought to be reported to, and be dealt with by, the superintendent. Except in case of emergency, however, trackmen should avoid undertaking any piece of work which they cannot expect to have completed for the safe passage of regular trains before such trains are due. On most roads section foremen are required to have the track clear 10 minutes before train time. As for irregular trains, it is to be expected that they must be held occasionally, if trackmen have not been notified of their coming; but here is where "tall swearing" is too frequently indulged in.

Before appointing any man as section foreman the roadmaster should examine him thoroughly and be satisfied that he understands clearly how to signal trains on that particular road. The foremen should thoroughly instruct their men regarding signals, and entrust them only to those who are careful and reliable. The men oldest in point of service are usually the ones to rely upon, because of their experience; and also because careless or irresponsible men are not, or, at least, ought not to be, retained long in the crew. Trackmen should not disturb torpedoes, fusees, or other signals found placed along the track, but they should always endeavor to ascertain the cause for their having been placed there. Torpedoes unexpectedly knocked off the rail or exploded by the hand car should be replaced. This rule makes it necessary for section men to carry torpedoes on the hand car.

On almost all roads there is a signal used between trainmen and section hands for the purpose of getting information regarding the time between trains supposed to be running close together in the same direction, as, for instance, the different sections of a train. Although such signal is not usually authorized by the company, it often serves a useful purpose, nevertheless; and as railway men will use it anyway, I shall say a few words regarding the same, by way of correcting some wrong ways of giving it; for misunderstanding sometimes results from making it improperly. A trainman desiring information of a trackman whom he is passing, after an inquiring look or gesture, holds out both hands in front of the body, one hand over the other, the palms together. If the section man answers by holding both hands out a *little way* apart, one over the other, it indicates to the trainman that the train ahead passed but a short time previously; if the hands are extended *far apart,* one above the other, it is supposed to indicate that the train ahead passed a long time previously *for that class of train.* The same signals, when given by a trainman, in answer to an inquiry from a trackman, indicate to the trackman that the train following is known to be near or far, as the case may be. If the difference in time is as much as 10 minutes, but less than 20, the person, after giving a signal that the trains are close, holds up both hands with all the fingers extended. A shaking of the head by the person answering indicates that he is either in doubt or else does not know. In giving the signal it is important that one hand should be held vertically above the other, instead of extended apart horizontally, on account of the latter being the customary sign of recognition or "hello," among many people, especially among railroaders.

Trackmen and trainmen should not be too free in motioning one another; for when such matters become habitual it might, in case of need, be difficult to tell whether or not only a jest was intended; and tomfoolery should have no place around the railroad. It is all right, and often very convenient, to interchange signals when each party understands the other; but trainmen should put little confidence in information gained from men whom they do not recognize as trackmen, or whom they do not know; and then, only when they act as though they understand what they are doing. Trackmen wishing to hail trainmen for information should not bother the engineer if, while the train is approaching, they see they can catch the eye of the fireman, a brakeman, or the conductor, perchance stationed somewhere out on the train. The foreman or trackman who gives the signals should stand aside from the rest of the crew, near the track, and he should not talk or yell while signaling with his hands. Men just coming from other roads should be careful how they use signals familiar to their experience on the road from which they came, lest in the new place these same signals have different meanings.

While a train of any class is passing, all trackmen should habitually quit work, straighten their backs and take special notice of the locomotive, with reference to signals carried, and look for a signal from any part of the train. Too often men get into the habit of jumping into some kind of perfunctory work "while the trains are passing," keeping one eye on the train and taking note of nothing on it except the presence or absence of the roadmaster or some other "big boss." After a train has passed, the foreman is not always sure that he made careful observation of the locomotive for signals carried, especially if he was looking for a note to be dropped; and if he then wishes to put his car on the track, it is important to have the corroboration of his men as to whether signals were carried for a second section. If the men are permitted a minute's breathing spell while trains are passing they will usually take interest in observing the signals carried by the locomotive or anything unusual about the train. If anything is wrong with the running gear they should signal the trainmen to stop. On the Baltimore & Ohio R. R. section foremen, track-walkers and other watchmen, pumpers and fuel keepers at pumping and fuel stations where there is no telegraph office, are instructed to assist in keeping trains the proper distance apart. When on duty they are expected to display a green signal when passenger trains are closer than ten minutes apart or freight trains closer than seven minutes apart. These signals, unless waved violently, are not intended to stop trains, but to notify the engineer that he is running too close.

The roadmaster's office, when sending out new train schedules, as changes in the same are made from time to time, should recall and destroy all the old ones, thus making sure that they will be no longer used by the employees through mistake or oversight. On some roads a blank form is supplied to each foreman or other employee to whom a train schedule is sent, on which he acknowledges receipt of the schedule, stating the time he understands it is to take effect.

160. Slides.—Slides are most liable to occur in the spring, just after or during the breaking up of winter, when the ground is loosened up by the departure of the frost. Whenever there is the least likelihood that a slide can reach the track at any place the train dispatcher should be notified and trains should be given orders to run slow by that point. Slow signals should be set at the proper distance, and in addition a watchman should patrol the track just ahead of every train, carrying a shovel, so as to be able to remove any slight obstruction. A "speeder" or railroad velocipede is a convenient aid for a watchman in case he has to look after slides separated some distance, as with such means of locomotion he can get over a good stretch of track in a short time. It is important, nevertheless, that trains should be run under control, because a slide is just as liable (and perhaps more liable) to come down while a train is passing as at any other time. This time of the year is when a foreman should be particularly on the alert, and the best service he can render is to keep his eyes open and take precaution. If there comes a sudden change in the weather and a thaw is about to start, he should drop what work he can, or get out of bed, if it be at night, and send reliable men over those parts of the track where there is any probability of trouble, going himself to the point where he has reason to think the greatest danger is.

Small slides of material so soft that it will not lie on the slope of the bank, but which will accumulate at the bottom sufficiently to fill the ditch and pile up against the rail, are bothersome, because every shovelful taken away only makes room for more to follow. When the ditch gets filled water is held, the effect of which is to soften the foot of the bank, which will then have a tendency to slide out and cover the track. If the ditch is at the foot of a high clay bank it is important to keep it open, because then the water from above may pass off without soaking through or into the foot of the bank, and if the foot can be kept from softening too much, the top, at the worst, can only slide over it and adjust itself to a suitable slope. The best way to keep a ditch open under such conditions is to take measures before it is filled. One method which may be followed is to drive stakes at the back side of the ditch, jabbing or picking the holes through the frost, as well as may be; and if the stakes cannot be set firmly enough to hold, the top of the stake may be braced with a leaning piece footing against the end of a tie. Behind these stakes plank or old ties may be piled, one on top of the other, to hold the loose material which slides down the slope of the bank. This piling up of the soft material gives to it an easier slope than that of the original bank, so that the tendency of the surface to slide is decreased and at the same time, while the sliding pressure is held by the stakes and braces at the bottom, the plastic material so held only serves to weight down the bottom of the slope the more firmly. In this way it is usually an easy matter to take care of what loose material comes over the top of the abutment and to keep the ditch open. Any clay bank may be expected to give trouble so long as its foot of slope is allowed to soak in standing water, and there is no use in clearing away slides with the expectation that the bank will finally take a slope and cease to give trouble; as long as the foot of slope remains unstable the onward movement of mud will be endless. If, however, the ditch can be kept open and the foot of the bank from sliding, there is some hope of bringing the trouble to an end. Another method of taking care of thin mud and keeping the ditch open is to clean out the ditch and cover it over with planks, allowing free passage for the water below. Old ties may be used as cross pieces and the planks may be laid close together, parallel with the track. The planks make a good bed to shovel upon, thus facilitating the removal of the mud, and the foot of slope is enabled to drain itself out. Sawed ties or old bridge timbers laid side by side across the ditch are also used in such places.

In springy cuts where the banks are of soft material some means of under drainage will serve to keep the slope surfaces dry and prevent small slides or "sloughing off." As elsewhere stated, tile drains laid diagonally down the slopes, at intervals, are sometimes used in places like this. Another plan is to lay blind drains of loose rock in the slopes at right angles to the track. These drains are sometimes made as large as 3 ft. wide and 4 ft. deep. They carry off the water and act as buttresses for the support of the slope.

Where heavier slides are threatening or have previously occurred, it may pay to drive a row of piles along the back side of the ditch or at the toe of the slope and back them up with planks or with a wall of old ties. This is a means of protection frequently employed. One of the most valuable lessons of track engineering is to see the need of adopting measures to avoid a repetition of trouble that occurred some year previous. In through clay cuts on some parts of the Canadian Pacific Ry., in the Selkirk mountains, it has been found necessary to drive rows of piles at 5 ft. centers at the back side of the ditch on both sides of the track. To prevent these piles from being crowded toward the track by the pressure of the sliding bank, the two rows are braced apart by log struts passing under the track. Eight feet outside each row at the ditch line there is another row of piles driven at 3 ft. centers and braced against the first row. These outside rows are backed by a wall of logs and the space behind is filled in with gravel, to facilitate drainage.

One way to quickly clear away a slide, if the surroundings are favorable, is to tie sticks of dynamite together and shoot them off. Large quantities of mud can be thrown out in this way, but the scheme works best where the explosives may be placed behind rocks or stumps that are mixed in with the soft material. A large rock may be broken up by placing a charge of dynamite on top of it, covering the charge with dirt or mud or with a smaller rock and then firing the charge. The material of slides has also been removed by hydraulic operations. At a point on the Southern Pacific road in northern California, in 1890, a slide 300 ft. high and containing 9000 cu. yds. of earth and slaty rock was removed from a cut in nine days in this manner. The water was conducted to the site of operations through a 12-in. lap-welded pipe laid in 30-ft. sections. Twelve pumps with a combined discharge capacity of 3300 gals. per min. were used, taking steam from the boilers of four locomotives on side-track The nozzle employed was 3 to 4 ins. in diam., according to the character of the material. The average discharge of water under a pressure of 45 to 50 lbs. per sq. in. was 2000 gals. per min., and the material was carried off in a sluiceway. The operating force consisted of 30 laborers besides eight firemen, machinists, pump repairers and experts to handle the hydraulic jets, at a total expense of $200 per day, including fuel, making the expense about 20 cents per yard of material removed.

About the quickest way to get trains past a big slide, where there is room, is to lay a new piece of track around it, close to the material which has slidden down, and then cut the old track, throw it over and connect it to the ends of the new piece. If the arrangement is to be only temporary and trains are to run at reduced speed past the slide, no great pains need be taken with the curves or with the surface of the stretch of new track. There is an advantage in this arrangement, in that the work train, by using the track between the regular trains, may be employed in getting the material out of the way. The track may be moved over as the slide is cleaned up, until the old track is uncovered. In some cases where a detour track is laid at a slide it pays to put the run-around in good surface and alignment and to wait awhile before attempting to clear away the slide. The material can be easier handled if allowed to dry out some, and as a rule not so much material will slide down if that which came first is allowed to lie until the ground settles a little. After the material has dried out it will usually pay to handle it with a steam shovel.

A cause of numerous accidents to train operation is falling rocks, which, like slides, are most liable to come down at the breaking up of winter. Thawing ground and hard rains will sometimes cause large rocks on steep mountain slopes to let loose and tumble onto the track with great force. The action of frost, the softening of rock by disintegration and the expansion of ice in crevices will also dislodge large masses from ledges or from the shattered sides of blasted rock cuts from which the loose pieces have not been carefully examined and removed at the time of construction. The sides of mountains and hills which rise at a steep incline from the track should be thoroughly hunted over for hanging rocks and loose boulders that are liable to roll down upon the track during some spell of bad weather. To protect the rails from damage when large rocks are blasted from or rolled down a mountain side, the track may be covered with old ties piled up to form an incline over the ditch on the hill side; or the rails in the path of the descending rock may be temporarily taken up during some favorable interval between trains, which would usually be found on Sunday. Near Crawford's Notch, on the Maine Central R. R., a large rock on a steep rocky slope has been chained fast to prevent it from rolling down upon the track.

161. Washouts.—Washouts, often less expected than slides, occur in times of high water, caused by sudden thawing, continued rains or cloud-bursts. A man on the ground can usually foretell a washout some time before it takes place, by the action of the rising water and the appearance of things in general. It is of utmost importance, then, that during the severest rain storms the foreman and his men should be out patrolling the track with the hand car, leaving a man supplied with signals to guard each place which seems to be threatened, and continuing the inspection until it covers the entire section. Should the track become impassable for trains the foreman will of course protect them with signals and then promptly notify the roadmaster and the trainmaster of the nature and the extent of the obstruction. Where proper vigilance is exercised by the track forces it is seldom that trains need be in danger of running into washouts, and great damage to the track can oftentimes be avoided. There have been instances almost without number when, if some man equipped with a shovel had happened along at any time during an interval of three or four hours, he could in a few minutes have turned the course of the water which later caused a bad washout. Trestles, bridge abutments and approaches; the roadbed at culverts, opposite old water courses down side-hill and along parallel streams (especially small streams) are the points most liable to damage by high water. At trestles or culverts over streams in which ice or flood trash is running men should be stationed with long poles to push obstructions clear of the bents or openings.

At the time of each flood foremen should take measurements from top of rail to the extreme high-water level and report the same to the roadmaster, with the number of the bridge or opening. Records of this kind should be kept in the roadmaster's office for future reference, being useful when the size of bridge or culvert openings must be decided upon. It is a good plan to make a permanent high-water mark at each opening, by driving a spike or chiseling a mark on the abutment masonry. At trestle bridges it is also useful to make float observations of the velocity of the stream, so as to obtain data for determining the volume of water passing, which may be needed at some future time when it is desired to fill in the trestle and contract the waterway. It is just as important to get such data at small streams as at large ones, and perhaps even more so.

In time of high water foremen should be vigilant to stop the progress of the water when it begins to cut the banks or the roadbed. Ditch water which starts to gully out or cut deeper should be particularly watched. A push car is a handy thing to have on hand at such times. A truck-load of material thrown into the right place at the right time may avert much damage. Tendency to cave or form gullies may be checked by the use of brush or old ties, or by throwing in riprap stone or bags of sand. When the water rises high and threatens to wash across the track and undermine it, the ballast may be protected by laying bags of sand on the upstream side, or planks may be placed along the edge of the ballast and secured to stakes to stop the wash of a side current. Where water of limited quantity is backed up against the track and threatens to rise over the top of rail it is well to spread the ties here and there and dig trenches to let it through, selecting places where the current is least likely to do damage. Backwater in which there is but little or no current may still do a great deal of damage if the wind begins to blow and dash waves against an embankment or the ballast. Means of protection above mentioned (sand bags or plank) may be employed in such places, and hay, straw or brush is sometimes thrown on the water to break the force of the waves.

When bridges or trestles have been carried away the rebuilding of the structures falls, of course, to the bridge department; and also when embankments are washed out for considerable distances or deep gullies are scooped out under the track, the bridge department is usually called upon to build temporary trestles, by driving piles or erecting framed bents, leaving the filling to be done afterwards. In such event the track department assists the bridge department by loading material, and on roads subject to washouts the roadmasters are provided with lists showing the number and size of the various pieces of timber required to build a span of trestle and lay the bridge floor thereon, so that when the roadmaster is called upon to load material it is only necessary to telegraph the number of bents or spans of trestle to be built. A pile driver having a 20-ft. extension, and capable of turning completely around on the car, so as to drive at any angle and straight in front without reference to the direction in which the car is headed, is recommended as the best machine for use in emergencies of this kind. The pile driver and the bridge outfit should be kept in good repair at all times and a supply of piles should be kept in stock whether there is work of this kind in sight or not. A pile-driver gang of 10 men, driving four piles to the bent, can complete 5 to 10 panels of bridge work in 10 hours of daylight and 3 to 5 panels at night, according to the conditions encountered. This estimate includes the bridge floor. Where the washout is a long one it is usual to put two pile drivers into service, working from both ends of the washout, or if only one machine is available and the work must be done in a hurry, a pile driver is worked at one end and the work of erecting framed bents is carried on from the other.

Another way of quickly throwing a bridge across a gap is by cribbing with logs, old timbers or new ties, spanning shallow streams, if necessary, with stringers laid upon cribbed piers. Where the current is swift the piers may be sunk and held in position by loading the crib with rocks, railroad iron or by sacks filled with sand or earth. The cribbing should be kept level as it is built up, selecting ties of equal thickness for the same course. Where it becomes necessary to make the crib or pier wider than the length of a tie a stronger structure may be had by building two piers together than by building the two separately. By laying two ties in each tier and forming the crib of several tiers each way, all built or bound together, a pier may be built up 30 ft., or even higher, quite substantially. If the bottom is soft the crib should be started on a floor of ties or timbers. Crib construction of considerable length or hight requires a good many ties, but with a train-load of ties on the spot a bridge can be put down in a hurry. On such occasions the work-train force is usually increased by all section men available, and if there is not opportunity for all of the men to work at the seat of trouble, part of them can be sent to load material. If there is not deep water to contend with and plenty of ties are on hand, a bridge can be built by cribbing more rapidly than by driving piles, since a larger number of men can be set to work. Sawed ties are best for this purpose. If the company's supply of ties is scattered along the road, the roadmaster should in such cases telegraph the track forces nearest them to begin loading without delay, using flat cars, box cars, or any other available empty cars, or cars that can be quickly unloaded, if necessary. It should be the understanding that if the foreman is pressed with damaged track about that time he may send a trusted man off the section to hire extra help and load the ties. The track department of a railroad ought to be so well organized that when things have to move all the roadmaster need do is to wire general instructions. If, however, the section foremen are customarily withheld from the exercise of authority in small matters somewhat aside from routine work, depending upon the roadmaster for instructions in full, the roadmaster in times of emergency will always have his hands full attending to details, and he will be greatly hampered in his attention to the work of chief importance.

Where an embankment has been side-washed, leaving some portion of the original embankment with the track overhanging, which is frequently the case where there are streams parallel with the track, there are several methods of putting the track into condition to carry the trains temporarily. One method is to level down the remaining portion of the bank, so as to fill the space washed out. The track is thus let down to a lower level, in a sag, and is later raised by degrees by unloading material at the side of the track, raising the track and placing the material thereunder, after the manner of ballasting. Another method is to throw the track over far enough to obtain a bearing the whole length of the ties and then to fill in the space washed out by dumping material from one side of the train, throwing the track back toward its original location as fast as the fill is made. This arrangement of throwing the track to one side is known as a "shoofly," and where there is a sufficient width of undisturbed bank, it is undoubtedly the best plan to follow. If the undisturbed portion of the bank is not wide enough at the top to support the ties their whole length it may work well to throw the track over and level down the bank deep enough to secure the proper width. Another method is to leave the track where it is and support the overhanging side by trestling. The stringers are placed upon caps which are supported on one side by the bank and on the other side by piles or posts driven or set in the space where the bank has been washed away. Where a post is used to support the outer end of the cap and the bank is not deep, it is usual to lay a longitudinal sill under the outside rail and set a plumb post, placing the cap on the post and digging out the bank so as to project the cap through for support on that side. Stringers are then placed under the outer rail, resting upon the cap, so that the embankment carries one side of the track and the stringers the other. If the embankment or space washed out is deep, a short sill is laid, running into the bank, and both a plumb post and batter post are set and sway-braced to the cap. By this method the track is carried at grade, on the old alignment, and the space washed out is later filled in with material brought by the work train. Where there is reason to fear that the portion of the bank which remains standing may not be able to support that side of the track it is well to reinforce the track ties

Fig. 470.—Surfacing Track over Shallow Washouts.

with switch ties 12 to 16 ft. long, placed 4 to 6 ft. apart between the track ties, one end of the switch tie resting upon the stringers and the other end upon a bed of track ties out on the embankment, thereby securing support for the track in case the bank underneath the track should cave or slide away. Where the top of an embankment has been washed off for a depth not exceeding 3 or 4 ft. the track surface may be evened up by cribbing and blocking with old ties, as illustrated in Fig. 470, utilizing pieces of plank and boards for shims.

For a very complete treatment of the subject of handling washouts with bridge forces, including the equipment of machinery, a list of the tools needed, the organization of the crew and the plan and procedure of the operations, the reader is referred to two reports on "Methods and Special Appliances Used for Building Temporary Trestles over Washouts and Burnouts," made to the Association of Railway Superintendents of Bridges and Buildings in the year 1895 by Mr. R. M. Peck, of the Missouri Pacific Ry., and Mr. Geo. J. Bishop, then superintendent of bridges and buildings for the Chicago, Rock Island & Pacific Ry. In order to show the practical application of methods of repairing track and bridges in time of washouts it may prove instructive to relate briefly the particulars of a general washout on the St Paul & Duluth R. R., in 1897, and the methods of work pursued in restoring the line to condition for temporary operation. A more complete account, with illustrations of interesting scenes at various points where damage was done, may be found in the Railway and Engineering Review of Sept. 11, 1897.

On the morning of July 3, about 3 o'clock, an unusually severe rain storm extended along the line of the road from Hinckley (76 miles north of St. Paul) to Duluth, centering in a cloud-burst at Mahtowa Station (43 miles north of Hinckley). The sudden and unprecedented downpour of water resulted in the Kettle river and its tributary stream, the Moose river, overflowing their banks and rising higher than any previous record had shown, and the culverts and other waterways through embankments, which had proven to be of ample capacity during 20 years of service, failed utterly to carry the large amount of surface water which flowed to them. At Rutledge (18 miles north of Hinckley) embankments, 15 ft. high, serving as approaches to a bridge of 125 ft. span crossing the Kettle river, were completely washed away, and at a point four miles farther north the earth approach to the bridge over Willow river was washed out for a distance of 200 ft. Eight miles farther north four bents of a trestle over Moose river were carried out. From this point north for 6 miles there was not a continuous mile of track that was passable. Stretch after stretch of gravel embankments 12 and 15 ft. high were washed out, leaving rails and ties suspended over gaps 200 to 300 ft. in length. At Barnum, 37 miles north of Hinckley, a 40-ft. through girder bridge over Moose river was carried away and the earth approaches for 300 ft. in length were washed out. From Barnum north to Duluth (39 miles) there were some 50 more washouts, varying in length from 10 to 300 ft. and from 2 to 40 ft. in depth.

As soon as the first reports were received, all the track and bridge forces available were mobilized in the vicinity of Mahtowa and work trains with material, men and pile driver were started north from St. Paul, getting 15 miles north of Rutledge by noon of July 3, the day of the storm. Two hours afterward the approaches at Rutledge went out, so that the trains were cut off from supplies, both north and south, and the work proceeded slowly and with great difficulty. The following methods were adopted for putting the track in temporary repair: In all washouts of 2 ft. or less depth ties, largely old ones picked up on the right of way, were laid under the track ties, two or three wide and a sufficient number in depth to make the necessary hight, plank being used to shim between the top layer and the track ties. Where the washouts were deeper than 2 ft., and up to 4 ft., two 12x12-in. timbers were placed at right angles to the track, 12 ins. apart; upon these were placed short blocks parallel with the track, and on these 12x12-in. caps, upon which stringers were placed, these bents being spaced about 12 ft. centers. In washouts of more than 4 ft. and up to 16 or 18 ft. depth, piers of heavy timbers and ties were built, 12 ft. apart, and stringers placed upon these carried the track. These piers were constructed with a base of not less than 12 ft. width, and wider than that where the hight required it. The first course of timber or ties was laid parallel to the rails and the next at right angles, and so on up, the several courses being drift-bolted together. No attempt was made to put the track on its original grade across the deep washouts: in such places the track on the embankments at each end was dropped down to make an easy run-off.

It was found that this class of work could be carried on rapidly. It required no dimension work or time to measure and frame timber, as would have been necessary in the construction of timber trestles. Many of these piers were built in running water 2 ft. deep. Piling was used only to cross swift running or deep water and in the washouts of 20 ft. depth or more. Gunny sacks filled with sand or earth were found to be effective in stopping and preventing the water from cutting into the embankments around culverts and abutments, and were used with success. On Thursday the 8th, at 6 a. m., the temporary repairs had been completed with the exception of the bridge over the Kettle river, where traffic had to be transferred pending the erection of a temporary pier of piles to support one end of the bridge, the masonry pier at that end having been undermined, when it settled, letting the span down 18 ins. and throwing it out of line. All of the temporary repairs were made with timber, no earth being handled except in leveling off for the timber foundations. As soon as the line was opened for traffic a steam shovel was started to work excavating material to fill around the many temporary structures, the caps and stringers being removed as the holes were filled up.

Bank Protection.—A railway which follows the course of a stream requires careful watching in time of high water, particularly where the roadbed slope extends to or into the stream. Where the stream bends toward the track in such places, or wherever the embankment slope is washed by the full force of the current, protective works are usually necessary to prevent the flood water from cutting away the earthwork and washing out the track. Protection is likewise required in many places on the slopes of embankment approaches to bridges at stream crossings, where the current at time of high water may strike behind the abutment with considerable force. The most substantial protection in all such places is a paved slope or slope wall starting on the hard bed of the stream or below the shifting material of the bottom. The Lehigh Valley R. R., where it follows the Susquehanna River, between Pittston and Sayre, Pa., is protected by a good many miles of very substantial construction of this class. This wall was built by the state to protect the Pennsylvania & New York canal, and the railroad was built on the tow path of the canal. Paved slope wall is, however, very expensive, and is seldom built these days. The means most largely used to protect embankments against the abrasion of stream currents, the wash of lakes, etc., is riprap, which is loose rock dumped or thrown over the slope to a depth varying from a mere covering to several feet, according to the force of the current. On bottom which is not subject to deep scouring little or no attention is paid to the foundation for riprap, except, perhaps, to gradually increase the thickness of the deposit toward the bottom of the slope, because if the water begins to cut under the toe or bottom the loose rock from above will tumble into the hole and stop the process. The effectiveness of riprap increases with length of slope or decrease in the inclination, and in recognition of this principle, specifications usually require that wherever the current may strike against the bank the latter shall be graded to a slope at least as easy as 2 to 1; or if the embankment has been finished to a steeper slope, the riprap shall be so placed that its upper slope shall be 2 to 1. In this same connection it is pertinent to remark that the resistance of an unprotected earth embankment to the action of flowing water improves with length of slope; this for the simple reason that where the material stands fully up to the natural angle of repose the slightest cutting action of the water will start the bank to caving, which loosens up the material so that the water makes short work with it; whereas, if the slope is easy the scouring action may go deep and far before the bank will begin to fall of its own weight. In turning a stream into a new channel the embankment across the old water course should be sloped off at least 2 to 1 on the stream side and well tramped down by team work.

Hand-laid riprap is work in which some of the stones are placed by hand, in order to make the covering of uniform thickness or to make the slope uniform. The necessity for hand work increases with the size of the stones. Some roads specify that riprap shall consist of stones generally as large as two men can handle, but much larger stones are frequently used as part of the material. Large pieces of rock should lie next the earth slope, and the foundation is usually started by digging a V-shaped trench to hold the stones at the foot of slope. If dumped over the bank too promiscuously many of the larger rocks will roll away from the slope or stand out where they will be easily dislodged by floating ice or drifting logs and trees. The best protection is obtained where the largest stones are in the bottom of the course, with the small stones chinked in between. It also effects a saving of material to pay some attention to the distribution of the stones over the slope. Where the slope is exposed to ice jams it is commonly the practice to throw in brush with the stones, to bind the riprap together. The butts are placed outward and downward in the stream. Where the current is too direct or too strong for heavy riprap to stand, as is frequently the case along rapid mountain streams, wing dams, rock-filled cribs or piles backed up by a wall of logs and trailing brush are commonly used to protect the banks from wash. Stone cribs are usually built up of logs or old bridge timbers notched into each other at the corners and drift-bolted. At intervals of 8 to 12 ft., according to the size of the logs and the force of the current, the outside walls are tied together by cross partitions of logs notched in between and drift-bolted to the longitudinal timbers. The empty crib is then filled with loose rock, and if it lies parallel with the bank the space behind is filled in with riprap. If it is not built up to the high-water mark it is made to serve as the foundation for a riprap slope. In the bend of a stream where the current strikes hard against the bank it is sometimes necessary to build wing dams or stone cribs extending diagonally into the stream, to turn the course of the water away from the shore. In such cases the bank behind the cribs is protected with riprap, and to prevent the water from cutting around the shore end of the crib the bank at that point is heavily riprapped or paved.

In order to withstand a heavy current, stone cribbing must have a good foundation, and such cannot be obtained on a sand or mud bottom. When built on such material the crib is liable to be undercut and roll into the stream. A good substitute on soft bottom is a bulkhead of piles driven 4 to 7 ft. apart and walled up behind with alternate layers of logs and brush, backed up with stone. The brush should be of large size, like the limbs of trees or small trees 3 or 4 ins. in diameter at the butt. These butt ends should be laid trailing to the current and project 4 or 5 ft. from the log wall, to guard the piles against driftwood and ice. The tops or branches lie in the space behind the log wall, which should be filled with stones as fast as the logs or large poles and the brush are laid up. To withstand the action of waves on a lake or ocean front, a type of pier construction consisting of two rows of piles with the space between filled in with stone, is commonly used. The piles are usually driven close together, but sometimes 2 to 3 ft. apart and walled up behind with timber. Along a stream, however, where there is a bank immediately behind the bulkhead, one row of piles with back filling is generally found to be sufficient.

On gravel or rock bottom the toe of riprapping will take care of itself, as already stated, but where there is some doubt about the stability of the foundation in the stream it is a good plan to cover the bottom with a layer of brush 12 or 18 ins. thick and 1 to 2 rods wide, and start the foot of the riprap slope on it. On the deep sandy bottoms of some of the rivers of the Mississippi valley, however, ordinary construction of this kind will not stand. These streams, and notably the Missouri river, among others, are continually changing their channels in many places, cutting away the banks on the outer side of the bends and forming sand bars next the bank on the inner side. During high water such changes take place very rapidly. The banks of the river, which are usually sand and silt, stand vertically 12 to 20 ft. in hight, and when a rise occurs in the river the scour at the foot of the bank undermines it and it caves into the river in slices of 5 to 10 ft. width. The saturation of the bank in nearness to the river is also another cause of failure, for if there be a stratum of quicksand it will run out when the water falls and cause the caving of an additional width of bank. Such caving of the banks is a constant menace to railway roadbed located in nearness thereto, and measures have to be taken

Fig. 471.—Weaving Mattress for Bank Protection, A., T. & S. F. Ry.

to protect the banks in order to save the roadbed from washout. The most successful protection as yet adopted is the use of woven brush mattresses, this being the standard form of protection used by the Missouri River Commission. Among other roads, the Atchison, Topeka & Santa Fe Ry. has done considerable work of this character. The protective structure consists of young willow and cottonwood saplings about 15 ft. long and 1½ or 2 ins. diameter at the butt, woven into a mattress about 12 ins. thick and usually 70 to 90 ft. wide. The willows are cut along the river shore, where they grow very thickly, in places, and hence long and straight, with but few branches. In preparation for the work a row of piles is driven along the river bank, a little below low water mark and 10 or 12 ft. apart. These piles serve as an anchorage for the mattress, which is woven on a flat boat (Fig. 471), on a triangular frame. The mattress is woven around the piles as the work proceeds and is slipped into the river by dropping the boat down stream. In weaving the mattress a wire cable of ⅜ in. diameter is woven in across the mat, opposite each pile, to which the cable is tied. Cables are also woven into the mat lengthwise, about

10 ft. apart, and at each intersection of the cross cables the two are fastened together, pulled up through the mat and made fast to a toggle consisting of a stick of cord-wood. After about 200 ft. of the mattress is woven, depending upon the depth of the water, the work of sinking it is begun, which is accomplished by wiring a row of large stones to the outer edge, and then following down stream with a boat-load of stones and dropping them upon the mattress. The stones used weigh from 20 to 60 lbs. each. After the mattress has been sunk the bank of the river is graded down to a slope of 2 horizontal to 1 vertical. This work is usually done by the use of a hydraulic jet operated from a pump on a flat-boat. After the grading is completed the bank is covered with riprap to a depth of about 18 ins. Figure 472 shows the completed revetment, and from the appearance of the trees in the background the reader will recognize the same stretch of river bank that is shown in Fig. 471, when the work was started.

Fig. 472.—Revetment Work by A. T. & S. F. Ry. (Progress View in Fig. 471).

The Chicago & Alton Ry. has done a considerable amount of revetment work of similar construction on the Missouri river, in the vicinity of Cambridge, Mo. At this place the first thing done was to grade down the bank hydraulically to a slope of 2 to 1 between the limits of 2 ft. above standard high water and 3 ft. below standard low water. At this place the mattress was woven of willow brush 1 to 2 ins. in diameter at the butt and 15 to 25 ft. in length. The mattress is 12 ins. thick and 86 ft. wide, and the inner edge extends to a contour line 3 ft. above standard low water and is tied at intervals of 16 ft. 8 ins. to dead men planted in the bank 8 ft. back from the top of slope. The mattress was woven with five lines of $\frac{3}{8}$-in. galvanized wire cable running longitudinally, each line consisting of two parts—one cable under the mattress and one on top; and at intervals of 16 ft. 8 ins. there are transverse cables running both under and over the mattress, these being the cables that are run to the dead men. While the mattress was being woven these crossed cables were held together at their intersections by wooden boxes 12 ins. square and 4 ft. long, open top and bottom and slotted at the corners, and after the brush had been woven around them the slack of the cables was pulled up with a set of blocks and falls and the crossed cables were fastened together with iron clips. The stones for sinking the mattress to the bed of the river weigh 100 to 200 lbs each, but as far as 3 ft. below standard low water the interstices of the mattress were filled with spawls. The slope of the bank from low-water mark to a contour 2 ft. above standard high water was then shingle-paved with one-man stone, which were generally delivered on wheelbarrows from a barge tied up alongside. The work of "paving," so-called, was started at the top of the slope and proceeded toward the water. In this way the stones lean against one another up hill, and thus slope away from the water, which is considered a more effective arrangement than where they slope toward the water, as is the case with paving that is started from the bottom of a slope. One paver with enough wheelers to keep him employed (usually seven) completed 1300 to 1400 sq. ft. of paving per day. After the paving was completed the crevices were filled and the top covered with a layer of spawls or crushed stone 2 ins. deep. In this work a mattress force of 33 men completed an average of 90 lineal ft. of mattress each day of ten hours. The force consisted of one foreman, 10 weavers, 10 brush passers, three laborers carrying the supply of brush from the barge, five laborers handling the cables, three laborers sinking dead men, and a water boy. The average cost of all work, including both labor and material for the mattress and the paving, was $746.62 per 100 ft. of bank protected.

Revetment work constructed as above described is found to be effective on the Missouri river, although failures have occurred where the current has flowed directly against the bank and proper care has not been taken to keep the slope patched up as damage has occurred. As the mattress never decays under water the protection of the bank against undermining is permanent. The problem of checking the cutting action of the stream is therefore that of keeping the upper part of the bank covered, which can be done by additions of stone from time to time.

162. Change of Line.—The engineering department of a road is sometimes called upon to improve stretches of the line by cutting down the grades, straightening out or eliminating curves here and there, or perhaps by moving the track out from the foot of a troublesome slide. Work of this nature arises most frequently on lines hastily built through hilly or mountainous country, where the development of traffic or a demand for increased speed of trains and heavier train loads in later years makes it incumbent or desirable to improve those portions of the road most difficult to operate or maintain. Methods of raising or lowering track in place are considered in connection with the subject of track elevation and depression, further along in this chapter, the object here being to take up methods of work involved in change of alignment.

Where the new roadbed is some distance from the old one it is customary to lay a piece of new track upon the new location and connect with the old track at the ends by cutting the old track and throwing it to the new alignment, when the time comes to make the change. If, however, the new location is near the old one and there is no serious obstruction between the two, the track may be moved over bodily to the new location, with less work than would be required to build it with new material or to take up and relay the old material. If the work is done in the right way, track handled in this manner need not be permanently impaired. In getting ready to move such a piece of track the ballast should be removed from between the ties as far as the shifted track is not thrown entirely off its bed, but not farther As such work offers a good opportunity for renewing the unsound ties, the spikes in all the worthless ties should be drawn before the shifting movement begins, thus leaving them lie in their beds and avoiding the handling of useless material. The sub-grade on the new location should be dressed off evenly, and if close by the old track it should be covered with ballast to such a depth that after the track is moved it will not require raising more than an inch or two to put it to final surface. Such preparation can be easily made if grade stakes are set to give the surface.

If the track is strongly embedded it should be lifted with a jack or lever before attempting to throw it; or it may be broken loose by having the men pry up the ends of the ties with their bars. A gang of at least 12 men is required to move a piece of track any considerable distance, and 15 or 20 men are none too many. There should be bars for all of the men. The practice of doubling up on the bars is hard on the bars and fatiguing on the men; the men discommode one another, they cannot exert their strength fully and easily, and much time is lost in getting ready for action, for one man must first plant the bar and then wait for his partner to get his feet adjusted between the ties and take hold. (The same objections apply to the practice of doubling the men on the bars when lining track in ordinary maintenance repairs). In order to make desirable progress on a big job it is necessary to have two or more gangs of men throwing on the track at the same time, one gang following up the other. In any case the track must be thrown by hitches, and it should be thrown each time as far as it will go without binding or springing back—usually not more than 2 ft., but depending to some extent on the number of men throwing on it and the manner in which they are distributed along it. If the track to be moved is straight and disconnected at both ends, the work of throwing may begin at either end; if connected at one end the throwing should first begin at that end. If the track is curved and is to be moved toward the outside of the curve, the throwing should begin at the disconnected end and progress toward the connected end; if the track is to be thrown toward the inside of the curve the throwing should begin at the connected end. In the last case it will help to keep the track from binding if the disconnected end is first thrown outward temporarily for some distance back from the end—that is, as though to straighten the track—in order that the middle portion may be more easily got even with the end. Where quite a long stretch of track is to be moved, it is best to let it remain connected at the ends and cut it loose in the middle, dropping a rail, or whatever length is necessary, in case the newly located line is shorter than the old one.

The length of rail necessary to make the connection after the track is thrown to the new alignment may be determined by calculation or by careful measurement with a steel tape. The best way to take this measurement is to set stakes on the line of the rails in the new position, using the surveyor's stakes on center line for a guide, and then take a measurement on the line of each rail separately. Unless the work is rushing, however, it is not worth while to bother about the connection until after the track is moved over, for it is a matter of but a few minutes to cut two pieces of rail to fit the opening; and the bolt holes at the joints may be drilled at any time after the connection is made. When cutting pieces of rail to make the connection, allowance should be made for closed joints, and joints pulled apart too widely, which will afterward need to be adjusted to proper opening. In case the excess of misadjustment is in joints pulled widely apart, it is only necessary to drive the rails together far enough back to make room for the connecting pieces, leaving the adjustment of the joints over the whole stretch to be made at any time after the connection is made. A good way to open the joints on a curve that is being lined in is to throw it a few inches past the center stakes in the rough lining, and then by moving it back to the stakes at the last, the track will stretch and pull the joints apart. It is just as well, also, to connect up temporarily with a pair of switch points and adjust the rails to their proper expansion openings before cutting pieces to fill the gaps. A great deal of work of the kind here considered must be done in gravel pits in order to move the track into the bank, after a cutting has been taken by a steam shovel or by a crew of men loading by hand, but in such places it is not necessary to go to much pains with the work, and the element of time is not so important as when moving main track.

In handling track in the manner described the ties must swing around askew to the rails, first one way and then the other, and by the

Fig. 472 A.—Throwing Track with a Lidgerwood Unloader; Before Pulling.

Fig. 472 B.—Throwing Track with a Lidgerwood Unloader; After Pulling.

time the track has been moved into its new position the ties will be out of square and need respacing; which can be easily done by two men working together, one on each side of the track, tapping the ties to proper position with hammers. In order to keep the ties properly spaced while track is being moved in short sections bodily (without bending), it is the practice with some to spike inch boards to the ties, parallel with, and outside of, the rails, but such an arrangement takes more time than is really gained, for it is an easy matter to tap the ties to their proper position with hammers after the track is thrown to its place. Where ballast is laid on the sub-grade before the track is thrown over, the track will usually be in condition to let trains pass slowly as soon as it is thrown approximately to line and connected, and the ties straightened, without doing any surfacing. Before the ties are ballasted they should all be placed squarely across the track, held up with bars and the spikes tightened down to the rail flange. On busy roads such pieces of work, if on main track, are usually done on Sunday. The train dispatcher should always be notified of the change, and trains should receive orders to slow up at the place until the track is safe for full speed. Slow flags or lanterns should be kept out until the track is in good running order.

In connection with the subject of transposing rails on curves mention was made of the practice of hauling strings of rails over the ties with a locomotive. The same method may be employed to haul a section of track endwise to a new position. The piece of track to be transported should be cut into sections as long as the locomotive can pull and then should be moved sidewise and thrown upon the track on which the locomotive is hauling. Attachment may be made by hooking a switch rope into a chain looped around both rails a little distance back from the end, with a strut placed between the rails to prevent them from being pulled together. The section of track is then hauled along on the rails, behind the locomotive, until it is opposite the point where it is to be used, when it may be moved sidewise off the track and thrown over to the new position. If only one section is to be hauled over the same track, the rails may be lubricated behind the locomotive. The occasion for work of this kind is sometimes met with in yards, and sometimes a switch lead or turnout is hauled in the same way. If the section of track or the turnout must be dragged over the ground, as for instance when hauling from a direction sidewise to the track, through a snatch block, a skidway of rails should be laid and lubricated with car oil. In order to prevent the ties from catching on the ends of the rails, the leaving end of each rail should be blocked an inch or two higher than the entering end of the next rail ahead. In some cases where track has been moved up or down a steep bank it was first cut into sections of four to six rail lengths each and one section was shifted at a time, over a skidway of rails, laying two skids for each rail length and hauling the section with switch ropes, through snatch blocks, or with block and tackle by the men. To stiffen the rails that are used for skids they are sometimes spiked to old trestle stringers.

For shifting track laterally to a lower level, in grade reduction work, the Grand Trunk Western Ry. has used a Lidgerwood unloader and cable, pulling down about 100 ft. of track at a time. In rear of the unloader car a flat car is coupled, and on the opposite side of this car from the track to be moved a snatch block is chained to a stake pocket to take the side pull of the cable attached to the track. To prevent kinking the rail where the cable is attached a piece of old rail about 10 ft. long is laid on the gage side of the near rail of the track to be pulled, and the cable is hooked around both. Figure 472A shows the cable attached and ready to pull, and Fig. 472B shows the same piece of track pulled down the bank. The track is usually moved in two hitches of 7 or 8 ft. laterally at a time. After pulling the track into the position shown, all the way through the cut, the unloader is then backed up and the track is pulled over to a level bearing and to its proper distance from the other track. The pulling can be regulated so closely that at this second movement the track is aligned sufficiently straight for the work trains, without the use of bars. This work of pulling track with an unloader is done very quickly, and at much less expense than by moving it with a gang of men throwing with bars. In fact, it is rather a difficult piece of work to throw track over the edge of a bank with bars, for after the ties begin to project over the slope the rail stands so high above the ground that the men cannot get a purchase with their bars. To throw a mile of track laterally and to a lower grade by hand labor requires the services of a large gang of men for a whole day, and the average expense on this road has been about $175 per mile. By using the unloader the track was shifted to place at an average cost of $43 per mile, the ordinary distance being 15 ft. laterally and an average of 10 ft. vertically. The time required to do the work in this manner averaged 7½ hours. The expense stated covers the use of the unloader, a locomotive and crew, four laborers and one foreman.

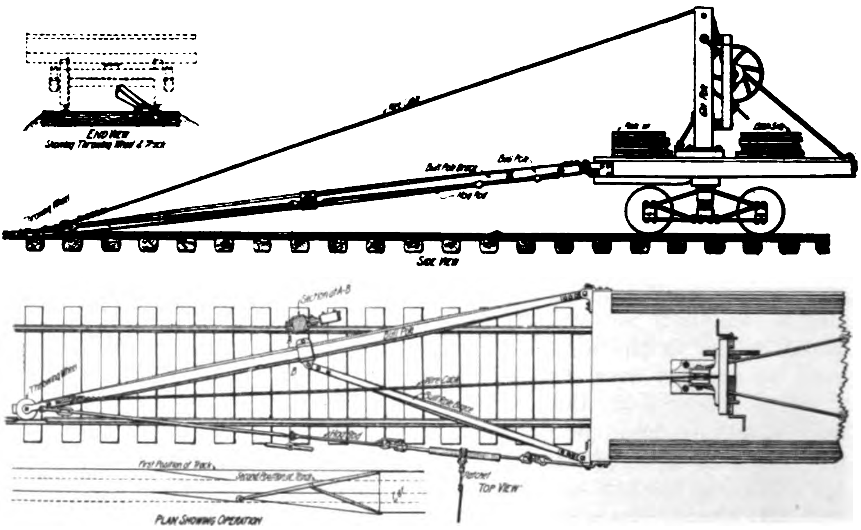


Fig. 473.—The Creese Track Thrower.

On the Pennsylvania and the Baltimore & Ohio Southwestern roads a machine has been used for throwing track in a general change of alignment, which employs the tractive force of a locomotive. The locomotive is coupled to a car provided with devices which exert a side thrust against the rail and shove the track out of alignment as the car is moved along, the operation resembling in some respects the trick of a snake when he crawls into a hole and closes the hole behind himself. The contrivance is known as the Creese track mover, being named after the inventor, Mr. D. C. Creese, formerly a carpenter foreman of the Pennsylvania R. R. The throwing arrangement consists in a stout pole 32 ft. long, known as the "bull pole," attached to a casting at the corner of a flat car and extending longitudinally in the track to exert pressure against the head of the rail through a 15-in. pulley at the end called the "throwing wheel." The general arrangement of the parts is shown in Fig. 473. This pole is braced about midway by a timber strut and stayed at the end by a 1½-in. "hog rod," adjustable by means of a ratchet pulling jack. Both the hog rod and bracing strut are attached to the opposite corner of the car from the bull pole connection, and the positions of the bull pole and its braces are reversible, making it possible to throw the track to either side, as desired. Before starting to throw track the ballast is removed from the ends of the ties, but not from between them, and a small section of the track is moved with bars in the usual manner. After this is done the pole is adjusted so as to crowd against the rail in its new position, and as the car is pulled forward or pushed backward by a locomotive the track is crowded over to its new position. At the rear end of the car there are two screw jacks, hinged to the decking, in position to be swung over between the end sill and the engine tender. Before starting to move track these jacks are screwed up, so as to stiffen the car against the tender. The car is also heavily loaded on either side with old rails, to give it stability. At the service end of the car a pulley is fixed at the top of a "gin pole" 9 ft. high, over which is passed a wire cable, worked by a crab on the gin pole, for raising the bull pole clear of the track when it is not in use.

On one occasion on the B. & O. S. W. R. R. a mile of track was thrown a lateral distance of 3 ft. with this car in three hours. The maximum movement was 20 ins., the car being hauled over the track two times at some points and three times at others. The cost of labor for the four men, and for the engine and crew operating it, was $17.50. On another occasion 2500 ft. of track was moved sidewise 11 ft. The minimum throw was 6 ins., the maximum throw 38 ins. at one time, and the track was moved over without taking out the ballast except at the ends of the ties. The time required to throw this length of track was four hours, and the cost, including the labor of four men, the engine and crew, was $16.00.

163. Policing.—Broken spikes, splice bars and bolts; castings, etc. dropped from trains; and other like material, should not be allowed to accumulate along the track, but should be picked up clean and carried to a scrap pile near the tool house. The best time to attend to such work is daily; for if a certain day is set for it each month it will either be forgotten or some other work will be on hand. In yards lumps of coal, pieces of car equipment, track material, etc., should be cleaned up each day, so that the yard may be kept clear and remove as far as possible from trainmen the danger of stumbling when getting on and off trains or when coupling or uncoupling cars. Whenever brake shoes, coupler parts or other pieces of car iron, or car doors, are seen lying in or near the track in going to work in the morning, the section crew should start early enough to have time to pick up such scrap material when homeward bound in the evening. Foremen should get the men into the habit of carrying to the hand car bits of iron and other scrap which may be found wherever work is being done. A good time to pick up scrap generally is during the winter, when the ground is bare, or in the spring, before the grass starts. At this time the right of way should be thoroughly cleared of all pieces of iron, old ties, large stones, lumps of coal and any other loose things which will hinder the mowing later in the season. A systematic way to do this is to divide the section crew each side of the track and walk over the right of way, clearing everything out of the way as the line advances, at the same time keeping the push car along to carry the scrap. Scrap which falls upon the track should be carried to small piles by the track-walkers. Freight dropped from cars should be taken to the nearest station and delivered to the agent, or shipped as marked, if there is no agent at a near station. At intervals of 60 or 90 days the scrap piles at the tool houses should be cleaned up and carried off by the work train or loaded onto a scrap car hauled by a local freight train. Work of the character here considered is commonly known as "policing." It includes a good deal of work not directly concerned in track surface or alignment or the safety of trains, but which nevertheless contributes toward general convenience and serves to preserve good order and a neat appearance in things generally along the line. Most of the duties coming under this description are elsewhere referred to, under one heading or another, so that it is not necessary to particularize to any great extent here.

Material lying along the track, such as lumber, ties, bridge timbers, etc., should be nicely piled, and proper clearance should be maintained, allowing no material to remain within 7 ft. of the rail on main track. The rules of some companies require a clearance of 8 ft., and some even 10 ft. from the rail, on main track, and as much as 6 or 7 ft. on side-tracks; on a few roads it is as small as 6 ft. for main track. The maximum out-to-out width of cars is about 10 ft. (the width of some furniture and Pullman cars will exceed this measurement by 2 or 3 ins.), so that the side of the car projects about 2½ ft. outside the track rail. To prevent injury to brakemen hanging from the sides of cars a clearance of 7 ft. is required. The rule requiring as much as 6 ft. clearance at loading tracks is continually transgressed and seldom strictly enforced. Such a rule puts shippers to great inconvenience, sometimes, and section foremen—who are supposed to see that the rule is complied with—must sometimes spend a great deal of time to little or no purpose trying to get shippers to observe the rule. If the required clearance on loading tracks was made 4 ft. there would still be 18 ins. of clear space outside of the widest car, and undoubtedly the rule would be more generally respected and heeded by shippers than a rule requiring clearance of 6 or 7 ft. Trainmen fully well understand that careless shippers will sometimes pile material dangerously near a loading track, despite the vigilance of the most alert section foreman, and therefore know what to expect in such places. In many cases the rules of the railway company are so unreasonable that shippers disregard them altogether and become very careless.

Section foremen are required to keep close watch for any encroachment on the company's right of way and to prevent adjoining landholders from erecting fences or buildings, altering ditches, obstructing culverts, piling material, building roads across the company's property or in any manner occupying the right of way without permission from the roadmaster or other official. Foremen should not permit fence wires or boards to be fastened to trestle posts or piles at waterways, as such will catch driftwood in time of flood, and might cause a washout. The piling of lumber, the erection of billboards, high board fences and like obstructions, and the planting of hedges, in the vicinity of grade highway crossings where they obstruct the view along the track, are a menace to highway travel and to train operation which should not only be forbidden on railway property but discouraged as much as possible on private land. In some locations it might pay railway companies to purchase lots and tear down buildings if by so doing a crossing watchman could be dispensed with. All trees, sound or unsound, liable to fall upon the track during storms should be cut down, whether on the right of way or private land. If permission to fell the trees cannot be obtained from the owners the foreman should consult the roadmaster. In some states railroad companies are permitted by law to condemn trees outside the right of way which endanger the track. It goes without saying that limbs of trees which obstruct trains or scratch paint from the cars should be trimmed or cut off. Foremen should promptly remove flood trash from bridge piers and abutments or trestle bents, and examine occasionally the sources of supply for water tanks or stations, clearing out accumulated leaves or drift of any kind tending to stop the intake. Culverts which have become partly filled should be cleaned out. Thick ice around bridge piling or small piers and abutments should be cut loose when thawing weather sets in.

Although the work of policing is important it is just as important that discrimination be exercised as to the amount of time devoted to it. Some men in authority are foolishly particular about the appearance of the track and seemingly ignorant about its real condition. On some of the most prosperous roads it may be well enough to spend time in cutting sod lines, scraping the ballast to a line on the shoulder and other fuss-work of like character, but on most roads the expenses of the track department are too closely scrutinized by the higher authorities to justify any such extravagance, and only such policing should be done as will serve some useful purpose, as already pointed out. Roadmasters should not fail to appreciate the foreman who keeps his track in smooth condition, even should his landscape gardening fall somewhat below standard, for there are trackmen who will spend time at cutting grass, picking stones and smoothing off the ballast when they should be surfacing the rails. As with useful men in all walks of life, the efficient trackman will not waste time on mere appearances.

The track forces should not be called upon to do puttering work around stations, such as making and attending to flower beds, mowing and watering lawns, scrubbing floors, cleaning outhouses, etc. Trackmen set at such work usually feel as though they ought to make the job last as long as possible, and agents or operators in charge at stations are not liable to discourage such inclination so long as the men will hang around (either at the stove or in the shade) and make themselves handy at doing chores. The readiness with which the foreman is generally expected to comply with requests to assist the agent might lead an outsider to think that track work proper is, after all, the matter of secondary consideration. It is clearly the duty of the track department to clean up the tracks around stations and loading platforms, but not the sweepings from the station. On any well regulated road the agent who would sweep dirt and rubbish upon the track would be expected to clean up his own muss. As for attending to the menial duties of the station agent no such practice should be permitted by the roadmaster. If clean floors and well-kept lawns at stations are advantageous to the transportation department, then that department should furnish its own labor to do such work, or authorize the agent to hire the necessary labor. On some roads the work required to maintain station buildings and grounds in neat appearance is performed by a floating gang of gardeners specially equipped for such service. Such a system is to be commended, for the practice of drawing men from the section for every odd piece of work performed on the company's property seriously handicaps the foreman in his appointed work. It may safely be stated that trackmen in general are required to do too much work which does not count on the track. Such work as the handling of heavy freight, assistance in car repairing, setting telegraph poles, stringing wires—and a good deal of it, too—often comes during that season of the year when track work of the greatest importance is pressing. If, then, under such circumstances the track gets down the roadmaster should not judge too harshly of the foreman. From all such work, as far as possible, the section forces should be excused; but if no other source can be called upon the foreman should be permitted to hire extra help afterward to make up for the time lost to the section; but even such an arrangement will not fully recompense the inconvenience of working the section short-handed at frequent intervals.

Aside from the plan of keeping the right of way in tidy condition as it is found, it will frequently work an advantage to improve the landscape. Much of the right of way that is turned over by the construction department is cut up with borrow pits and heaped with material wasted from cuts. A comparatively small amount of extra plowing and scraping, sometimes, will level down the most conspicuous of the high places, fill up unsightly hollows or round off abrupt changes in the surface, all to even better purpose than pleasing appearance. Elsewhere in this volume (under "Mowing," § 91) an instance is cited of the scheme of plowing, harrowing and seeding right of way, to put it into condition for machine mowing, at greatly reduced expense compared with hand labor. The substitution of a crop of grass for unsightly patches of weeds not only improves the looks of things but is an inducement for neighboring farmers to do the mowing without expense to the railway company. The sodding of slopes in cuts and on embankments is frequently a much needed protection to the earthwork.

The planting of trees along right of way for ornament has been occasionally proposed but seldom carried out. At least one case that is worthy of mention, however, is to be found along the "Old Road" (Michigan division) of the Lake Shore & Michigan Southern Ry., west of Adrian, Mich. In 1865 and 1866 European larches to the number of 16,000 and 20,000 chestnut trees were set out on this route, along both sides of the right of way, near the fences, about 50 ft. apart. The two kinds of trees were set generally alternating, a larch and then a chestnut. One object in this scheme was to stimulate the farmers to plant, but it appears that the example set by the railway company had but little influence. Most of these trees have thrived well. They have been trimmed to a stubby growth and have attained a good diameter, but many of the trees which have died out have not been replaced, which would seem to indicate that the practical results of the undertaking have perhaps not reached expectations.

164. Repairing Telegraph Wires.—Telegraph lines along railways are constructed and maintained either by the telegraph companies or by a special department of the railway company, and it is not intended here to enter into the subject of line construction and repair any further than to consider a few points with which the track department is most intimately concerned. Where the width of the right of way will permit, telegraph poles should be set so far from the track that they will not be liable to fall upon it in case they get broken off or pulled over during storms; this means a distance somewhat farther than the length of the pole out of the ground. The poles should be set to a good depth and the earth should be well tamped around them. A general rule for poles under 30 ft. long is to plant them one fifth of their length in the ground. The rules of the Western Union Telegraph Co. require that in earth excavation 25-ft. poles shall be set 5 ft. deep, 30 and 35-ft. poles 5½ ft. deep. the depth increasing 6 ins. for each additional 5 ft. up to a pole 60 ft.

long, which shall be set to a depth of 8 ft. In rock 25 and 30-ft. poles are set 4 and 4½ ft. deep, respectively. In soft material one-fourth part of coarse gravel or crushed rock is sometimes mixed with the dirt or sand to be filled in around the pole. Tools used in excavating holes for fence posts and telegraph poles are shown in Fig. 419. Engraving *C* shows a combined crow and digging bar, usually made in two sizes: octagon, 1 in. in diam., 7 ft. long, weighing 17 lbs.; and 1⅛-in. octagon 8 ft. long, weighing 28 lbs. Engraving *G* shows a combined digging and tamping bar made of either round or octagon steel, the size 1 in. in diam. and 7 ft. long weighing 19 lbs., and the size 1⅛ in. in diam. and 8 ft. long weighing 30 lbs. Spoons for excavating holes for telegraph poles have 6-ft., 7-ft. and 8-ft. handles, according to the general depth to which the poles are set. Engravings *B* and *D* show one style of blade and Engravings *F* and *H* another, the blade in the latter case being oval, 8½x10 ins. Tamping bars are made 8 ft. long, with either wooden or iron pipe handles, that shown as Engraving *A* having an ash handle shod with an iron tamping head.

The usual number of telegraph poles to the mile varies from 32 to 35, for an ordinary load of wires on straight line, to 40 poles on curves. The minimum length for telegraph poles has generally been 25 ft., but 20-ft. poles are being used to a considerable extent where not more than two cross arms are carried, as they are cheaper, are not subject to so much wind pressure and carry the stress from the wires better. In using poles of good length, however, there is the advantage that they may be cut off at the ground and reset when the buried part becomes decayed. It is desirable to keep the tops of the poles to an even grade, as nearly as may be practicable, and in order to do this some of the poles may be set a little deeper than others, using poles of extra length in the depressions. It is undesirable to have abrupt changes in the elevation of the line, for if an insulator pulls off or a tie wire breaks on the high pole the falling wire is likely to sag to the ground. Where there is a change in the hight of the poles or a sudden change in the topography it is well to make the difference in elevation gradually, by grading up or down, about 2 ft. to the pole. On curves the poles should be set up against the lateral stress of the wires sufficiently to prevent being pulled past the vertical position. Where there is a large number of wires in a curved line the lateral pull is usually counteracted either by bracing the poles with leaning posts or by setting the poles to rake or lean outward to the curve of the line. Poles that carry a good many wires around a sharp curve are sometimes raked 15 deg. or more, and on soft ground they are frequently guyed or braced besides. Where the line turns a corner or a considerable angle the pole should be braced or guyed. Wherever the line crosses the track the poles should be deeply set and well braced. On side hill the poles, if practicable, should be set on the down-hill side; otherwise they are liable to be carried toward the track by land slides or snow slides, by falling rocks, or by gravity, in case they become broken off or pulled over in time of storms. In districts where the heavy storms come always or nearly always from the same direction the poles should be set on the leeward side of the track, or the side "away from the wind;" otherwise, and no serious objections to the contrary, they are set on the side on which most of the stations stand, so that it will not be necessary to carry the line over the track.

Although linemen are employed to look after the telegraph lines of railways, yet it often happens that they cannot reach a break in the wires for some hours after it occurs; and as it is indispensable that the service of the wires be maintained as continuously as possible the section men should temporarily connect the wires whenever they find them parted. Lines running through woods are especially troublesome, owing to falling trees; but poles are struck by lightning occasionally and frozen sleet or high winds will break down the wires and break off or pull down poles carrying a heavy load of wires. In order to get the wire in working order it is only necessary to connect it and keep it off the ground. This can be done by pulling it so taut that it will hold itself up, or by stringing it along a fence or propping it on crotched sticks. An extra piece of wire is needed to tie a broken wire together, and, as a coil of wire is rather bulky and bothersome to carry every day on the hand car, coils of repair wire should be cached in places along the track, about a mile apart, known to all the hands; say near each mile post. When broken wires are found an endeavor should be made to connect each wire of the line and to keep the sagging wires apart. As soon as the wires are found down, a piece should be cut from one of the wires to tie up the rest, and while doing this two or three men may be sent with the hand car for wire to connect the line from which the piece was borrowed. In connecting wires temporarily on a curve they should be placed on the outside of the curve, so as to pull against the poles; otherwise, if they pull loose from their fastenings they might swing over to the track. The railway company's division wire—that is, the one used by the train dispatcher—should be known to the section men, and this wire, if down, should always receive first attention. No extra tools are needed for this work, as the wire has only to come in contact, and if twisted together with the hands it answers all purposes temporarily. For cutting the wire there will usually be a file on the hand car, or certainly a track chisel. Draw the wire across the edge of the chisel and strike the wire with a hammer, when it may be easily snapped in two. If no tools are at hand the wire should be twisted in two with the hands, so as to get at least one wire connected as soon as possible. After the wires are tied up the foreman should report the matter to headquarters as early as possible, stating the pole number, or just where the break exists, the number of poles broken or to be plumbed, and the number of insulators and cross arms broken, if any. If the wires are crossed, or in contact, and cannot be reached, the matter should be reported immediately to the nearest telegraph office.

Section foremen are usually instructed to trim trees which stand near telegraph lines, to prevent the branches from touching the wires when hard winds are blowing, and to inspect the line carefully after storms. Should section men or others sent to look for a break in the wires between two stations not find it on their section, they should either notify the men of the next section or else go on until the break is found, or until meeting repair men sent from the opposite direction. Wherever it is necessary to trim trees that stand on private property, such as shade trees or fruit trees, the aim should be to do the work in the spring, before the foliage starts, as permission can be most easily obtained at that time.

165. Disposition of Old Ties.—As an average for the whole country, about 400 old ties per mile are taken out of the track each year after the first five or six years from the time the track is built. About the best way to dispose of them on high fills is to let them slide endwise down the slope until they find a resting place. There they will be out of the way, will help hold the slope from sliding down, and, after rotting, will encourage the growth of brush, blackberry vines, and other vegetation, which is desirable on high fills or on steep side hill to hold the banks from being washed by rains. But in other places they are only in the way and must be disposed of at least cost, or to profit, when they can be put to some use. In summer, while busy renewing ties, section men have but little time to bother with old ties, except that they ought always to be trucked out of cuts within a day or so of the time they are removed from the track, and it is a good plan to take time at the end of each day's work to throw old ties into piles at convenient distances apart. Such clearing up adds much to the appearance of things, and where there is grass or weeds it facilitates mowing to have the old ties picked up. In this shape they are easiest disposed of.

In some localities old ties are eagerly sought for fuel, and people will often render some service in exchange for them. Of course the section men ought to have such things gratis. The foreman should require that all people who haul away old ties shall take them as they come, rotten ones with the rest, so that no further attention on his part need be paid to cleaning up. Old cedar ties or ties of other soft timber badly rail cut, but otherwise sound, are sometimes relaid in side-tracks, staggered, so that the cut portion does not come under the rail. Such old ties also make good fence posts. Redwood ties cut out in the tracks of the Southern Pacific Co., in California, have been sold for 15 cents each for this purpose. Old ties may be used for cribbing or walling up the foot of side-hill or embankment slopes. If the embankment is composed of gravel or other loose material a wall at the foot of the slope aids much in keeping the material from rolling down, or from being washed down by rains. Old ties can often be used to good advantage at washouts, as elsewhere explained, and wherever the condition of things is such that repair material is frequently in demand, a supply of them should be kept on hand at all times, at points convenient for loading. It is desirable to pile such material in places where it can be burned when it becomes too much decayed for service.

Old ties may also be used for building temporary loading platforms at side-tracks, for blocking freight on cars, at freight stations, for fuel at pumping stations and for locomotive kindling. Such fuel does not produce as much heat as cord wood, but it costs the company nothing except the cutting, and where wood is scarce and coal dear it undoubtedly pays to utilize old ties in this way. At Alliance, Ohio, the Pennsylvania Co. has a shearing machine for cutting and splitting old ties and other old timber into locomotive kindling. The machine shears the wood into blocks of any desired length, at the same time splitting the block into proper sizes for use. The capacity is about 10 cords of wood per hour. The Chicago, Burlington & Quincy Ry. also has, at its Western Avenue shops, in Chicago, a bulldozer machine for the same purpose. The machine has a vertical knife for cutting off and a horizontal one for splitting, and makes about eight strokes per minute. The power required to drive it is 15 h. p. Two men handle the ties at the machine, but when they are taken from a flat car an extra man is required to unload, and ordinarily two men remove the wood in wheelbarrows and pile it up. The total cost for unloading, cutting, splitting and piling is 37½ cents per cord, as against 78½ cents per cord when the ties were cut up with a circular saw and split with a pneumatic machine. At one time the engineering department in charge of the Toledo division of the Pennsylvania Lines West gathered statistics on the work of handling and cutting up old ties for locomotive kindling, to make a comparison with the cost of cord wood, which, in that locality, was quite "cheap." The report showed a slight difference in cost in favor of the old ties.

By winter time old ties which have been piled during the summer or fall will have become dry enough to burn, and all which cannot serve some useful purpose should be so disposed of. For kindling, a quantity of old waste may be picked up along the track and soaked with car oil or kerosene. Then during some forenoon when the wind is not blowing hard, preferably in damp weather or when the ground is covered with snow, the section men may go along and set fire to the heaps, placing a bunch of the oily waste in the bottom of each pile, at the windward end. An ax should be carried along to split off a little kindling where such is necessary to get the fire started. Then during the rest of the day the crew should be so divided that the men can come along about an hour apart to poke up the fire and throw together such piles as have fallen apart; thus done, there will usually be but little left of the old ties by the time the fire dies out. In this way the "picnic" of burning old ties need not last a week, as it often does where the whole crew is allowed to walk around together among a few piles, to visit and play with the fire. Of course due precaution and watchfulness must be exercised in setting fire to certain piles where the wind is liable to carry fire and damage fence or other property. Wherever convenient, in piling old ties, the pile should be made around a stump or old log on the right of way, so that both may be burned at the same time. After old ties have been burned the ash heaps should be poked over for spikes and stubs. When burning old ties it is a good plan to put all the old spikes on hand in the fire. In this way the grease and scaly rust are removed and cracks in defective spikes are shown up.

166. Taking Up Track.—The work of taking up abandoned track should be done according to some system, for, on general principles, every piece of material lost requires that the railway company must, in time, buy a piece to replace it. All the spikes should be pulled and put into boxes or kegs, and stubs of spikes, in ties sound enough to be used again, should be driven down. It is well to pull all the spikes before the rails are taken up, because if the spikes start hard the tie, without the weight of the rail to hold it down, may not lie firmly enough in its bed to admit of pulling the spike. The men should try to pull the spikes without bending them unnecessarily. Each pair of splices should be coupled together loosely with the same bolts that were used in them while in service, so that the bolts will not be lost. It is not worth the while to spend much time on nuts securely rusted fast to the bolts, because in many cases the bolt will twist in two before the nut will loosen. If the nut refuses to turn after exerting a reasonable amount of strength on it, time will be saved by knocking it off with a hammer. Where the track has not been much used the bolts are likely to be found somewhat rusted, and it is a good plan to squirt a little car oil on the thread of the bolt outside the nut; this will save time both in taking off the nut and in putting it on again. If the bolt sticks fast it should not be driven out, as such treatment may injure the thread, but the splices should be struck a side blow with a hammer, when usually both splices and all the bolts will come loose.

In taking up a piece of track of any considerable length, where the material must be loaded on cars from behind, there is more work than one might at first think. There must be a crew large enough to lift a rail and shove it onto the car—say at least 10 men—and then, since much time would be lost if the men were to stop work to shove the car ahead a rail or two at a time, it is cheaper to have a team to haul the car. An untrained team is sometimes not able to start a flat car after it is half loaded with rails, and must have the assistance of the crew, one or two of the men using pinch bars on the wheels. Under such circumstances it is best, when the car is once started, to haul it about 10 rail lengths before stopping, and then to use the team to drag the rails forward to the car for the men to load, beginning at the rear and hauling away as fast as the spikes are pulled and the splices taken off, so that as soon as the men are ready to load they will not have to wait on the team. If the ties are to be loaded two cars will be required, unless the disposition of the material will admit of piling the ties on top of the rails on each car. Three improvised stone sleds are a good means of conveyance. Part of the men may loosen the ties and load the sleds, and the other part load them onto the car, while the team hauls the empty and loaded sleds back and forth. The spikes, splices and bolts should be loaded on the same cars with the rails from which they were taken. A pair of splices coupled with bolts through two holes next one end, dropped straddle the side of a stake pocket, serves well for a car stake to hold the rails on the flat car. Pieces of rail too short to reach past three stakes should not be put on the outside of the car, lest the jarring of the car may cause them to shift endwise and fall off, between stakes. The foreman in charge should take note of the number of pieces of material put on each car. On a certain piece of work a gang of 10 men, with a team, took up and loaded 1200 ft. of track (2400 ft. of rails) without the ties per day of 10 hours. This figure is an average for the work of several weeks. The ties remained in place undisturbed and the rails and fastenings had to be loaded on cars hauled over the track which was being taken up, as the work progressed. The conditions were somewhat unfavorable, the claw bars being poor and the track slightly up grade, so that the men had to assist the team in moving the cars after they became half loaded.

Where the grade of the track is ascending appreciably a team and 10 men cannot move loaded cars to any advantage. In such case a work train is needed and, of course, it then pays to work a crew of good size. As it is both undesirable and costly to have to carry rails very far by hand, and as there would be insufficient room for a large crew to work when hauling the cars only a rail's length or two at a time, the most rapid method of taking up track with a work train and crew is about as follows: Pull the spikes from the rails, both sides, for 300 or 400 ft. at a stretch, without removing the bolts. Then throw each string of rails off the ties, cutting loose at the joint where the spike-pulling was dropped. By means of chain attach the two strings of rails to stake pockets at each side of the hind car, hooking the chain up short enough to hold the end of the rail off the ground. Then pull ahead with the train, dragging the rails along on the shoulders until the rear rail is opposite or past the end of the undisturbed track. Before pulling on the rails see that they are turned so that the nuts will not drag underneath. The whole string can be overturned easily by lifting simultaneously with several claw bars, catching the flange of the rail between the claws of the bar. While part of the men are taking off bolts the train can be backed up and the rest of the men can load the ties, which should be hauled ahead to the cars by team. Then, after the ties are loaded, the men should mass on the rails and pitch them on broadside as the flat car is hauled along opposite the spot where each rail is lying.

At one time the Flint & Pere Marquette R. R. (now Pere Marquette R. R.) had a piece of track to take up, and to avoid legal complications did it on Sunday. No spikes or bolts were loosened, nor was the dirt, which covered the ties badly in many cuts and at log railways, removed before the appointed day. In eight hours, between 8:20 a. m. and 5 p. m., one gang of 230 men took up and put over the end of the train the rails (56-lb.) on 6½ miles of track and two side-tracks. All frogs, switches, spikes, bolts and splices were picked up clean and loaded. No machinery was used, except some hastily constructed rollers on the cars and at the end to run the rails over.

In the work of improving the grades on the Wyoming division of the Union Pacific R. R., during the years 1899 and 1900, the company built 158 miles of new track on cut-off lines, saving 30.47 miles in distance and abandoning most of the old track. At the same time grades of 68 ft., 75 ft. and 98 ft. to the mile were reduced to a maximum of 43.3 ft. per mile, compensated (For a full account of this work, see the Railway and Engineering Review for Feb. 9, March 16, Aug. 10 and 17, 1901). In loading the material taken up on the abandoned tracks two methods were employed, one of them being novel and ingenious. On part of the track taken up the rails, ties, etc. were carried back from the rear of the train to the cars on which they were loaded by means of a Roberts track-laying machine operated in back motion (for description of this machine see § 30 and Fig. 35). The only modification necessary to adapt the machine to the work was to put live rollers on the tie extension of the "pioneer" car, which brought up the rear of the train. The train, in order from rear to front, consisted of pioneer car, two rail cars, locomotive, four tie cars, one box car and a caboose. Ahead of the train there was a gang of 12 to 20 men pulling spikes and removing splice bolts. All bolts except one were taken from each splice, and on tangent where the ties were in good condition the spikes were drawn from all ties except two under each rail. On the train and in the rear of it there was a gang of 42 to 44 men, distributed for the work as follows: Two men removing splices, 12 men pulling remaining spikes and lifting rails, 2 men gathering and carrying spikes, 12 men taking up ties, 4 to 6 men handling rails on the cars, 10 men handling ties on the cars. Working in this manner, the rails and ties had only to be lifted from the roadbed and placed on the rollways of the machine, which carried them forward to the cars whereon they were loaded. At the first side-track back of the point where the track was being taken up a gang was kept busy transferring rails and ties from the flat cars loaded by the machine, to stock, gondola and box cars, for shipment. Here all the ties were sorted into three grades: (1) good for main line; (2) good for side-track; (3) good for contractors' use in temporary lines on earthwork haul with light locomotives. The rails were sorted into three classes: (1) for relaying in main line and for use in important sidings; (2) for use in ordinary sidings; and (3) scrap. This transfer gang was also drawn upon for extra men needed at the front. When the work progressed continuously 6000 ft. of track could be taken up and loaded per day, but as cast iron pipe in culverts, telegraph poles, good timber from pile and framed trestles, and frequently fence posts and buildings, were loaded up and hauled away, the average daily progress was less than 4000 ft. of track taken up and loaded, including other material, as stated.

Although this method of handling the material was exceedingly convenient, and the only practicable one for rapid handling in localities where cuts and fills were numerous, yet on the plains, where teams could be used alongside the track, the latter was the more economical. As much of the track on the old location followed the surface closely there was a good deal of opportunity to use teams to advantage. The drawback with the machine loading was the necessity (for convenience of transportation) of transferring the rails and ties from the flat cars on which they were first loaded, to other cars; but for this the machine method would have been the more economical in all cases. As it was, the ties were hauled back by teams and loaded directly into box cars, sorting them as they were loaded. This gang had a flat car at the rear rigged with an extension over the center of the track, which carried a concave dolly about 2 ft. above top of rail, forming an incline on which the rails could be shoved up. Ahead of this car were the rail cars with dollies through the center, by which means the rails were sorted and shipped without transfer. Ahead of the rail cars were box cars for ties, then the engine and the caboose.

167. Purchasing and Handling Ties.—Ties bought at points along the road are usually delivered at side-tracks and piled up at the owner's risk until counted and accepted by the railway company. The piles should be made not nearer the track than 6 or 8 ft., according to the company's established rule for clearance in matters of this kind, and generally not farther from the track than 25 ft. The most convenient way of piling is to throw the ties together loosely, as cordwood is piled, about 4 ft. high, in piles not too long, leaving a space occasionally for walking through. This is about the way men will habitually pile them, because in such shape they are more conveniently handled over than when piled in square piles. For convenience in loading cars the ties should preferably be piled on ground not lower than the track. It is important to have the ties in the piles lie endwise to the direction of the prevailing winds, and off the ground, so as to get the best possible circulation of air for seasoning the timber quickly and for drying out the pile rapidly after rain storms. The best way to secure this arrangement is to lay in place for each pile two rows of old ties for a foundation. It is best to use old ties for these bottom rows, because they will not be taken up when the new ties are loaded, but will remain to invite later parties to pile their ties in the same place, thus securing an arrangement to suit the company without exacting any special requirements. Each kind of timber should be piled by itself. The foregoing covers about all the rules for piling ties that can be successfully exacted from the persons who have them to sell. After the ties have been handled over, inspected and counted, or while doing so, they should then be piled in the best manner for seasoning.

It is generally understood that ties season best when piled in square piles. One way of arranging them in such piles is in courses alternately parallel with and perpendicular to the line of the track. Ties sawed on four faces should be spaced an inch or two apart in each course, and the outside ties in each course may be turned on edge, so as to make an air space both over and under the intermediate ties of every course. This method applies to ties sawed on four faces but not to pole ties. The best way to pile pole ties, and in fact all ties, for that matter, is in layers of two one way, parallel with the prevailing winds, and eight the other way. Pole ties may be laid touching in each course or layer, but ties that are squared up on the sides should be separated by a little space, to allow for free circulation of air and evaporation. This method of piling is not so compact as the other and the winds have a better chance to blow through it. For convenience of handling, the piles should not be more than ten layers high, and the ties in the top layer should be laid close and sloping, so as to shed water. For convenience of inspection the piles should be separated by some little distance, and for fire protection and to make room for teams the rows of piles should be widely separated. Ties which have been floated down streams or which have lain in water for a considerable time should be stacked in a vertical position, to allow the water to drain out properly. Creosoted ties are more inflammable than the natural timber and should be piled well clear of buildings. In the dry regions of the West the top layer of tie piles along the right of way is covered with dirt, to protect them from catching fire from locomotive cinders.

Ties are generally bought according to specifications, and are counted by a tie inspector in the service of the railway company. He is supposed to see both faces of each tie its whole length, as the tie is rolled over before him and the party making the sale, and to pass upon the fitness of the tie as to size and quality. Ties smaller than the standard adopted by the company are thrown out as culls, and, if sound and not too small, are generally taken at a reduction—usually at half price. But it is not customary to accept a quantity of culls exceeding in number some certain fixed percentage of the whole number received. The railway company, drawing from its experience from year to year, determines upon what proportion of its ties in culls can be utilized in side-tracks. The acceptance of a reasonable number of culls is also in line with proper economy of timber, and should have some influence toward delaying a general advance in prices, as in this way much timber is utilized that might otherwise go to waste. After being sorted over the number in each pile should be counted carefully, marking the end of each tie with white chalk as it is counted. Both ends of each tie as it lies in the pile should then be spotted with white lead paint, to preclude any liability that the company will buy the same tie again, some time. First-class ties may be daubed with a single spot on the end and second-class ties with two spots. If two or more tie inspectors are employed on the same line they use paints of different color, white and red being preferred. After the ties have been counted the inspector gives the owner a receipt or voucher for the ties accepted, and at the same time makes out a report of the same which he forwards to headquarters that night. Really this report should be a duplicate, in facsimile, of the

Fig. 474.—Incline of Tie Hoist for Ohio River R. R., Ceredo, W. Va.

voucher given the owner of the ties, for which purpose a pocket duplicate or carbon copy book arranged with half the sheets perforated, so that they may be torn out, comes handy for the inspector's use. When large quantities of ties are bought at a distance they should by all means be made to pass inspection before being shipped. When purchasing sawed ties from saw mills, where the ties are loaded as they come from the saw, the inspector is usually required to be on the car, to see and pass upon each tie as it arrives. Unsound timber is much more generally found among sawed ties than among ordinary hewn ties, on account of the fact that they are usually made from larger trees.

Switch ties should, if anything, receive closer examination than cross ties of ordinary length, on account of the higher price paid for them and the desire that the timber should be of the soundest quality. It is not always possible to get from the same party ties of proper lengths to make complete sets of switch ties, and such as can be had are therefore paid for by the foot, stipulating that not more than a certain percentage of the whole will be accepted in any one length. It is not always customary with people selling switch ties to square up the ends until after the ties are inspected by the railway company, because the length which each piece will make may be affected by checks and other imperfections, which the inspector is supposed to look out for. It is usual for the owner to have men on hand with a crosscut saw ready to cut off each stick for all it will make, as allowed by the inspector.

Where the railway company's full supply of ties can generally be had along its own line it should be stated in advertising for ties that none will be accepted from any person who has not previously made known to the company the approximate number of ties he would like to furnish, and who has not received the company's assent thereto. With this understanding there need be no danger of having more ties hauled into the yards than the company cares to buy, as has been known to happen, sometimes, during occasional years of "hard times." Throughout the eastern or Atlantic states ties are usually hauled out to the track during the winter months and loaded onto cars and hauled away during the spring. But when ties are to remain in the yard for some time the piles, after being counted, should be rearranged in a manner to promote thorough seasoning and to diminish the risk from fire.

The tie inspector should be possessed of many good qualities. He should be a man of experience, having good knowledge and judgment of the kinds of timber suitable for ties. He must also have the personal qualities of quick decision, firmness and moral courage to a high degree. Upon his decisions hangs the expenditure of large sums of money for the better or worse of the company's interests. He should be strictly honest, and of good address; but above all he should be a total abstainer from intoxicating drinks, for, no matter how honest his purpose may be, if he will accept a "friendly" (?) drink now and then there will be lacking no effort on the part of some persons to get him into careless moods at convenient times. By checking reports of ties taken out of the yards with reports of purchases made by the inspector, it is possible to know pretty certainly whether the inspector's figures have been accurately made. If, therefore, he turns over to the company ties of a general good quality, and there stands against him nothing worse than such reports as might be expected from interested parties, the railway authorities should not be too ready to receive insinuations that he is unfit for the position. A man in such a position has sometimes a hard road to travel, and unless he is very agreeable and possessed of a good deal of tact he may not be able to maintain friendly relations with everybody.

In some quarters ties are brought to convenient loading points by rafting, or by "driving" them loosely in streams and catching them at the desired point with a boom. At some such places hoisting plants are installed to convey the ties from the stream to the cars. As an instance, the Ohio River R. R. receives a large portion of its tie supply at Ceredo, W. Va., on the Kanawha river. The ties are floated down the river and held in a boom under the railroad bridge, where they are taken off the hands of the tie men. To transport these ties to the company's cars with facility and economy there is a plant for hoisting the ties up the steep bank and to convey them along a platform extending between two side-tracks, from which the ties are put aboard the cars. The hoisting mechanism is a conveyor constructed with an endless roller chain carrying sharp spurs at intervals and running in a shallow trough. It consists of two sections, the first extending from the river to the top of the bank (Fig. 474), a distance of about 125 ft.; and the second, from the upper end of the first, a

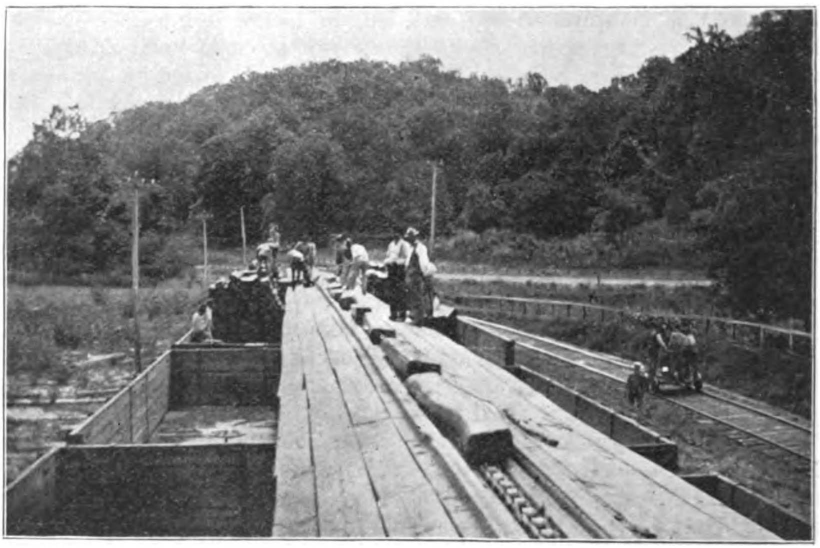


Fig. 475.—Loading Platform of Ceredo Tie Hoist, Ohio River R. R.

distance of 250 ft. on the level and between the tracks, as illustrated in Fig. 475. The foot of the incline hoist extends into the water a sufficient distance to admit of the floating ties being poled onto the moving chain. At either side of the chain runway there is a platform sloping toward, and projecting partly over, the cars, so that the ties are loaded onto the cars with but little effort. The chain runway is lined with strap iron to reduce the friction. The chain is usually run at a speed of about 100 ft. per minute, and is strong enough to carry a solid string of ties continually. It can, however, be speeded up to 150 ft. per minute, so that a capacity for carrying 800 or 900 ties per hour is possible. The power plant consists of a boiler and engine of 20 horse power. The Hocking Valley Ry., the Charleston, Clendennin & Sutton R. R. and the Kanawha & Michigan Ry. either have or have had similar plants.

168. Tie Preservation.—The increasing cost of timber, consequent upon the rapid destruction of the forests, has turned the attention of some railway companies toward timber preserving methods. It is estimated (1904) that upwards of 101 million ties are used annually for renewals by the steam railways of the United States, and 9 to 25 million more in new construction, and it is generally believed that consumption will soon overtake and exceed the supply of the diminishing forests. It has been proposed that to meet the situation railway companies should undertake tie cultivation by setting out forests of rapidly growing timber; or to relieve the annual demand, either by the use of metal ties or by preserving the timber by chemical treatment, or perhaps by both. The possibilities in tie cultivation have yet to be demonstrated, and although but relatively little has been done in timber preservation, in this country, yet the industry is considered as having progressed beyond the experimental stage. Such progress is not true of the metal tie, for, so far as American railways are concerned, it can hardly be considered that experimentation with metal ties has commenced with any degree of earnestness. Whatever tendency there is toward economy in the use of tie timber is therefore principally and almost entirely in the direction of chemical treatment.

Economy of Treated Ties.—Increase in the life of ties, obtainable within proper limits of expenditure, should operate to reduce the cost of track repairs in several ways. In the first place, the number of ties required for renewals within a considerable period is decreased in exact proportion to the increase in length of life; which carries with it, of course, a relative saving in labor for removing decayed ties. This saving is obviously greatest where the work of getting ties out of track, in renewals, is especially difficult and expensive, so that the logical procedure in beginning the use of treated ties is to first lay them under road crossings, in front of station platforms and in the middle or intermediate tracks of three and four-track lines, or wherever the main track is flanked on either side by a side-track. Since the renewing of ties always disturbs the surface of the track and impairs the bed more or less, it is readily seen that the cost of surfacing ought to decrease with increase in the life of the tie. More than this, many varieties of the cheaper woods are by preservative processes rendered available for tie timber where otherwise the life of the same would be too short for profitable use. This principle applies more especially to some of the soft woods requiring tie plates for the best results.

The money value of these advantages is readily calculable with close approximation except in the matter of diminished impairment of track surface. It is difficult to satisfactorily get at the ultimate cost of breaking up the embedment of ties in making renewals, but any trackman knows that it is an important item of maintenance expense. In renewing ties it is not practicable to at once get the new ties to take their proper share of the rail support. If the new tie is placed without dressing down the bed of the old tie the chances are that it will stand too high for some time, thus forming a "hump" in the track surface until the tie settles into the bed or until the rails cut into the tie to their proper level. If the bed of the old tie is dressed down it usually happens that the new tie will settle below the point where it can share in the rail support equally with the adjacent ties, thus throwing undue load upon the adjacent ties and eventually causing all to settle and impair the track surface. Again, in excavating the ballast to renew a tie the filling between the ties at that point is loosened up, thus impairing the surface drainage for the remainder of the season, so that during heavy showers or long-continued rain storms a disproportionate amount of water passes into the ballast and roadbed at such points. The ill effects resulting from such a condition are most readily perceptible in dirt-ballasted track, but in track well ballasted with better material, and well drained, it is not an unfamiliar sight in wet weather to find the ties "churning" at points where renewals have been made the same season. The fact that disturbance of filling and embedment in tie renewals is one of the principal causes of roughened track surface can be well established, but is perhaps not so forcibly apparent to all as it might be. That the degree of roughness in track surface produced by breaking up twice any assumed number of tie embedments per rail length is more than double that produced by disturbing only the given number, is too obvious to require detailed explanation.

So firmly am I convinced on these points that I would state my views of tie preservation economy in this way: Any preservative process which will double the natural life of the tie at a total cost for handling and treatment not exceeding the cost of the untreated tie—that is, doubling the life at an ultimate cost for the tie which is not more than double the first cost—is a paying proposition for any railway company. To double the life of the tie at an additional cost equal to first cost increases somewhat the direct money cost of the tie per annum, owing to interest on the extra investment, but against the interest charge there stands to the credit of the treated tie a reduction of half the expense of tie renewing, besides whatever saving accrues from the less frequent disturbance of tie embedment.

Let us take an example: Suppose that a pine tie costing 30 cents will last five years, and that by treating it at an additional cost (for handling, chemicals used, interest, depreciation of plant, etc.) of 30 cents the tie can be made to last 10 years. Looked at comparatively, the cost of the untreated tie will be 30 cents, plus 10 cents for putting it in the track, or 40 cents for five years' service, which is an average of 8 cents per year. The cost of 10 years' service for the treated tie will be 60 cents, plus 10 cents for putting it in the track, or 70 cents, which is an average of 7 cents per year—to which must be added a yearly interest charge on the additional investment of 30 cents. At 4 per cent this charge would be 1.2 cents, or a total average yearly cost for the treated tie of 8.2 cents, as against 8 cents for the untreated tie. Figured on this basis, 0.2 cent per tie per year, or a yearly cost of $5.60 to $6.00 per mile of track, is the price paid to avoid disturbing the embedment of all the ties once in 10 years. Expressed in another way, the advantage which accrues to stability of tie embedment and track surface by reducing the average tie renewals from one-fifth to one-tenth of the whole number each year, is secured at a yearly cost of five days' labor per mile of track.

That such is a favorable showing from the standpoint of economy, no one who understands how the conditions of rail support are affected by disturbing the embedment of the ties will be likely to dispute, but a simple calculation will remove any doubt. The average life of untreated ties of all kinds is about 6½ years, so that, on the average, something like 440 ties are removed from each mile of track each year. Assuming that chemical treatment will double the life of the ties—which, further along, is shown to be a fair estimate—the use of this agency will reduce the annual number of removals by 220. The cost of bar-tamping ties in gravel ballast, including digging out and filling in again, ranges from 2¼ to 6 cents each, according to the price of wages ($1.10 to $1.50 per day) and various conditions of the work, such as hight of lift or depth of open space under the ties, amount of material removed in opening out the ties for tamping, interference from trains, size and quality of the gravel etc.; but the average of a number of carefully kept records is 3.7 cents. In general practice new ties put into the track during renewals are either raised high and shovel tamped, or are bar tamped, at the time they are laid, and a few days later they receive another tamping with bars. On a large number of roads, however, perhaps the majority of heavy-traffic roads, it is considered necessary, in order to restore the original conditions of embedment, to give all new ties two extra tampings during the season of renewal. Where they do not receive this amount of extra work it is reasonable to suppose that the track surface will suffer in consequence. The advantage in reducing the number of tie renewals by 220 per mile per year is therefore an actual saving of from $8.14 to $16.28 of money that would otherwise be expended in tamping the new ties up to a proper bearing under the rails. This saving stands against the $5.60 or $6.00 representing, as above, the extra cost of treated over untreated ties, but the actual economy may be in much greater proportion, even if not calculable in dollars and cents, for there is no telling how much of the general work of track surfacing may be due to the settlement of old ties that are overburdened through lack of support from new ties lying adjacent. It is a matter of only ordinary experience to find new ties hanging by the spike heads, and particularly is this liable to be the case if there is a good deal of rain shortly after the ties have been placed. There are certain other indefinite advantages with the tie of long life, such as reduced wear and tear on rolling stock, due to the better average surface which results from the less frequent disturbance of the ballast.

Figured on the basis of a different financial system the showing is all the more favorable to the treated tie. The annual interest charge at 4 per cent on the amount necessary to purchase the untreated tie and place it in the track (40 cents) is 1.6 cents; and an outlay of 7.4 cents at the end of each year, if invested in a sinking fund, is sufficient to replace the tie in the track at the end of five years. The annual cost of the untreated tie is then $1.6+7.4=9$ cents. In the case of the treated tie the annual interest charge on the cost of placing it in the track (70 cents) is 2.8 cents, and the annual outlay toward a sinking fund sufficient to replace the tie in the track at the expiration of 10 years is 5.8 cents. The annual cost of the treated tie is thus seen to be $2.8+5.8$ cents$=8.6$ cents, or 0.4 cent in favor of the treated tie. Figured on either basis, higher first cost of tie, higher rate of interest or longer life for the untreated tie gives a less favorable showing for the treated tie. Thus, at a first cost of 40 cents, interest 5 per cent and a life of 6 and 12 years, respectively, for the untreated and the treated ties, the treated tie would cost 0.3 cent more yearly than the untreated tie; and at a first cost of 50 cents for the tie, interest 5 per cent and life of 6 and 12 years, the difference in favor of the untreated tie is 0.59 cent yearly—figured on the basis of borrowing the money to purchase the tie and to replace it by a sinking fund, in each case. From the standpoint of actual outlay, the economy is therefore greater the shorter the life of the untreated tie. Another way of looking at the question is to compare the ultimate costs of both kinds of ties for a term of years, adding compound interest. The total cost for an untreated tie costing 40 cents placed in the track and renewed at the end of 5 years, compound interest at 4 per cent, is $1.079 at the end of 10 years; and the total cost of the treated tie costing 70 cents placed in the track, interest compounded at the same rate, is $1.036 at the end of 10 years.

The foregoing discussion will serve to outline somewhat roughly the possibilities of tie preservation methods at an assumed increase of life of 100 per cent and a cost of treatment which is relatively high—an extreme case, so to speak. As a matter of fact, much better results than anything above calculated upon have been and are being obtained, so that in general cases there can be no doubt regarding the question of economy. This much further may be said regarding the general economy of tie preservation: Decrease in consumption of timber, due to increased life of preservative methods, ought to tend toward cheapening the first cost of ties, or at any rate to reduce the first cost to a figure far below what it would be were no efforts put forth to economize in the use of timber. A large percentage of the ties used are made from young timber, and by continually cutting out the younger trees for ties the growth of timber for other purposes is greatly hindered. If by preservative processes the life of the tie can be doubled, not only will the effect be to decrease in inverse ratio the rate of timber depletion, but also the saving of that much standing timber will enable the supply to more nearly keep pace with the demand. It must be apparent that the influence of such a saving on the timber supply of the country ought to be very great. The immediate result to the railway companies of such improved methods in the use of timber should be a two-fold economy, in that (besides the diminished consumption) by drawing less upon the timber supply the price of timber must inevitably be cheaper than it would be if the original rate of consumption was maintained.

Decay of Timber.—The natural decay of timber is caused by fungi, a vegetable growth consisting of innumerable microscopic plants, which consume the starchy matter in the wood and dissolve certain parts of the material which constitutes the cell walls or fiber. The fungi include a large group of a low order of leafless, colorless plants, the mycelia or thread-like sprouts of which penetrate the interior of the wood structure and excrete a ferment which dissolves certain constituents of the wood fiber to produce the food supply for the plant. The familiar punk and toadstools seen on trees and dead timber are the fruit of these fungi, and give off the minute germs or spores. The conditions essential to the germination and growth of these fungus threads are moisture, heat and the presence of air or oxygen. Regarding the condition last named it is generally known that timber which is continually submerged does not decay. Investigations of the Forestry Division of the U. S. Department of Agriculture show that wood containing less than ten per cent of moisture is not subject to decay. In respect to heat the fungoid growth requires moderate warmth, 40 to 120 deg. F. being the practical limits, and about 80 to 85 deg. the most favorable temperature. In a freezing temperature the fungi cease their activity and do not multiply, which accounts for the longer life of railway ties in cold climates. If, however, the temperature be raised to 150 deg. the fungi die, and in such temperature the wood, for the time being, is disinfected or sterilized. Thus it is that with many kinds of timber, if kept dry, the development of the fungi is extremely slow or absent entirely, for long periods, thereby insuring long life for the timber. But the condition most favorable to the growth and activity of the fungi is the fermentation of the sap. The sap of timber consists of water holding in solution quantities of sugar, albumen, starch, gums, oils, resins, acids, etc. When wood seasons the water in the sap evaporates, leaving the sugar, albumen etc., distributed through the pores of the wood in the solid condition. Of the substances named the most putrefiable is albumen, which is readily soluble in water. When moisture is taken into the wood the albumen goes into solution and sets up fermentation, induced by germs of fungi contained in the sap or in the knots of decayed limbs that have been closed over by the growth of the tree. If, however, the albumen is once coagulated it is afterward soluble only at high temperature and high pressure. The object aimed at in timber preserving processes is, therefore, to either coagulate the albumen or to remove the sap and replace it with some sterilizing agent.

The coagulation of the raw albumen may be effected by simply heating the timber, and such treatment is really all there is of one method of timber preservation, referred to further along. The simplest process for removing the sap is to soak the timber in water, preferably running water, for a considerable length of time. This process is known as "water seasoning," the theory being that the sap is diluted and gradually displaced—that is, removed by solution. This action is, of course, much accelerated by boiling or steeping the timber, but so far as actual practice is concerned neither method is employed to any considerable extent. A few experiments in "water seasoning" are said to have demonstrated the value of such treatment, and it is generally conceded, or at least generally supposed, that rafted lumber is more durable than lumber which has not been submerged in water. The method of removing the sap resorted to in general practice is to steam the timber in a closed retort, the consequent expansion of the cell walls driving out a portion of the liquid within the timber, and then to subject the timber to a vacuum, which causes it to expel the remaining portion. But while it is evident that the total or partial removal of the sap from the wood greatly retards decay, it is known that it only delays the progress of decay, for germs will enter the cells and propagate, in the presence of moisture, even if all the sap has been removed. To effectively preserve timber it therefore becomes necessary not only to remove the sap, but to sterilize the fiber against fungus growth by impregnating it with an antiseptic. The antiseptics most commonly used in this country are in the form of a vegetable oil or a metallic salt in solution, forced through the pores of the wood. The antiseptic would be proof against organic life, even if injected in the presence of the sap, providing thorough penetration could be had, but if the sap is not removed the entrance of any preserving solution through the cells of the wood is resisted by it, so that only shallow penetration into the wood can be had, thus leaving the interior still liable to decay.

Although many processes of preserving timber have been experimented with, in this and other countries, only four or five methods of treatment or combinations of the same have assumed commercial importance. The four principal methods are: (1) the vulcanizing process, (2) creosoting, (3) burnettizing, and (4) kyanizing. In Europe a fifth process, namely boucherizing, or impregnating with sulphate of copper, has been used to some extent, and a combination process known as the zinc-creosote treatment is also being used. Of these four processes only two have yet come to be recognized as practicable or profitable for extensive use, namely, creosoting and burnettizing. The former process, which consists in removing the sap from the wood and injecting into it creosote or dead oil of tar, is the more effective of the two, but the latter is the cheaper. It differs essentially from the former only in the liquid injected, which is the chloride of zinc ($Zn\ Cl_2$). Owing to the cheaper cost burnettizing has come to be much more extensively used in this country for tie preservation than creosoting, while for pile timber creosoting is used to the exclusion of the other, since under water zinc chloride is soon washed out. Creosote is also considered protection against sea worms, at least for a time, while burnettizing is not, although it is thought that if the chloride solution could be held in the timber it would be effective for this purpose; and a method intended to accomplish the retention is referred to further along.

Vulcanizing.—Vulcanizing, which is sometimes called the "roasting" process, consists in subjecting the timber to heat under pressure. It was invented by Mr. Samuel Haskin, and is sometimes also called "Haskin's process." The timber is run into a retort or long cylinder, which is then closed, and the first operation is to remove surplus moisture from the outside of the timber, due to casual exposure to rain or snow; but no attempt is made to expel the sap from the wood. The heat for this purpose is obtained by turning steam into a series of pipes. The air is first compressed to a pressure of 150 to 200 lbs. per sq. in. and then passed through a water separator, to remove the moisture, after which it is pumped through tubes heated by live steam and thence through a pipe system heated over a coke furnace, whereby its temperature is raised to 400 or 500 F. It is then delivered to the timber treating cylinders and kept in constant circulation by sending it in cycles through a circulating pump. The duration of this heating process is about eight hours. The cost of treating pine lumber is $8 to $10 per 1000 ft. B. M., and something more for hard wood. The cost of treating 6x8-in.x8 ft. pine ties is about 25 cents each. The process in this country has been worked by the New York Wood Vulcanizing Co., with a plant in New York City. In this plant there were four treating cylinders 6 ft. in diameter and 105 ft. long. In London, England, there is a plant worked by the Haskin Wood Vulcanizing Co.

The principal use of vulcanized wood in this country is for ties, guard timbers and planking in the floors of elevated railways. The Manhattan Elevated Ry., in New York; the Union Elevated Ry., in Brooklyn and the Northwestern Elevated R. R. in Chicago, are some of the roads using it. The timber that is generally used is southern yellow pine. Vulcanized ties and guard rails of this wood on the Manhattan Elevated Ry., in New York, have stood service longer than 17 years, but they showed signs of deterioration at that length of time. The life of untreated ties of the same kind of timber in the same service was six years.

The theory which is urged in support of the vulcanizing process is that the heat coagulates the albumen and the distillation of the sap transforms that liquid into various wood-preserving compounds, such as acids, wood creosote, etc., which are prevented from escaping from the wood by the pressure under which the treatment takes place. These substances finally solidify and seal up the pores of the wood. The pressure serves also to keep the wood from checking. The wood is therefore supposed to be impregnated with its own chemical products, or, as a German authority has said, "fried in its own fat." An analysis of a vulcanized oak tie, made at Columbia College some years ago, found that it contained 11.91 per cent of substances traceable to the action of high temperature on wood, including oils, turpentines, carbolic acid and resinous acids. Yellow pine timber treated by this process is said to have shown greater strength than before treatment. This view is supported by tests made at the Stevens Institute of Technology, Hoboken, N. J., in 1884 (See Railway Review, Feb. 21, 1891, page 123). This effect is due probably to the large amount of vegetable oil or pitch which, after distillation at the high temperature, solidifies and acts as a sort of filler between the fibers. On the other hand the claim that vulcanizing timber increases its strength is denied by some who profess to have made careful tests. One fault found with the process is that, however valuable may be the transformed liquid as an antiseptic, it is too thinly distributed throughout the timber to be highly effective; and another is that wood creosote, which is one of the important results of the process, is not an effective preservative of timber.

Creosoting.—Creosoting, as already stated, consists in impregnating the wood with a product obtained from the distillation of either wood or coal tar, called creosote. The coal-tar product is properly known as "dead oil of coal tar" and, strictly speaking, is not creosote, for creosote is a vegetable product and is not found in coal tar. Dead oil of coal tar contains a good deal of carbolic acid, and as creosote proper and carbolic acid resemble each other very much in smell, the two products are confounded by the commercial use of the same term for both. Among English-speaking engineers it is quite commonly the practice to refer to the two kinds of material as "coal-tar creosote" and "wood creosote." German experts usually observe the distinction and do not associate the term creosote with dead oil. Coal tar creosote distils at a temperature of 480 deg. F., contains naphthalene as its principal antiseptic element and is insoluble in water. Wood creosote is obtained from the destructive distillation of pine timber and contains paraffine as the principal antiseptic. Another important antiseptic property of both is due to the large percentage of carbolic acid contained. Dead oil is heavier than water, weighing about 8.8 lbs. per gallon, and before exposure it is colorless. The napthalene contained in dead oil melts at a temperature of 174 deg. F., and when once liquefied and entered within the wood cells it solidifies and becomes permanently fixed. Its specific gravity at the boiling point (212 to 220 F.) is 0.9778.

Creosoting is done in two different ways. In the Blythe process there are three stages: seasoning, extraction of sap and moisture, and the injection of oil. The ties, if not well seasoned, are sometimes kiln dried, so as to evaporate all moisture possible. They are then placed in large cylinders, to which live steam is admitted and held for several hours. The object of steaming is to liquefy the portions of the sap which have solidified during the process of seasoning. After the steam is let off the air is exhausted and a partial vacuum is maintained for a time, the result of which is that the moisture and the liquids formed by the steam in the interior of the timber are expelled and the delicate enclosures of the sap cells are broken down, clearing the way for ingress of the oil. While the vacuum is held heat is maintained by steam coils, to prevent the vapors from condensing and remaining in the timber. After the products of this treatment are drawn off the cylinder is then filled with the hot oil at about 175 deg. and held under pressure until the desired absorption has been obtained. In the Bethell process of treatment the oil is applied by pressure in the same manner but without previous steaming.

The details of the process as carried out at the works of the Southern Pacific Co., at Houston, Tex., are about as follows: The timber is run into a retort, which is then closed, and a vacuum of 22 to 24 ins. is set up and held about 10 minutes. Live steam is then turned in, destroying the vacuum and raising the temperature of the timber, and after 15 or 20 minutes another vacuum is pumped to open the pores of the wood. After holding the vacuum for 15 or 20 minutes live steam is again turned on and the pressure held for 6 to 8 hours, care being taken not to permit the temperature to exceed 250 deg. F. After blowing off the steam a vacuum of 24 to 26 ins. is again set up, the timber and retort meanwhile being held at a temperature of 225 deg. by a heating process. This (third) vacuum is maintained from four to six hours, after which the expelled liquids are drawn off and the cylinders are filled with creosote oil at a temperature of about 170 deg (to make it sufficiently fluid to enter the wood), when the pumps are again started and the pressure is raised to 80 or 100 lbs. per sq. in. and maintained from one to two hours, according to the quality of the timber. The average time of treatment is from 18 to 20 hours and the average absorption 1.2 gallons or about 10½ lbs. of creosote per cubic foot. The average cost of treatment has been as low as $10.23 per 1000 ft. B. M., for a year's work. Of this amount $8.26 represented the cost of the creosote oil, $1.23 the cost for labor, 59 cents the cost of the fuel and 15 cents the maintenance of the plant. At the works of the Norfolk Creosoting Co., Norfolk, Va., the timber is first subjected to the action of live steam for five to seven hours at a pressure of 35 to 55 lbs. per sq. in., the temperature not to exceed 275 deg. F. unless the timber is water soaked, in which case it may be permitted to reach 285 F. for the first half of the period. At the expiration of the steaming the chamber is emptied of sap and water and a vacuum of at least 20 ins. is set up and maintained at a temperature of 100 to 130 F. for a period of from five to eight hours, or until the discharge from the vacuum pump indicates, by absence of odor and taste, that the timber has ceased to expel sap. The chamber is again emptied of sap and water and the oil is admitted and pumped to such a pressure as will cause the absorption of the desired quantity per cubic foot or the desired depth of penetration into round timber, as computed from the readings of the measuring gages.

Creosoting is conceded to be the most effective of all timber treating processes. It is the process almost universally used in France, and in England it is more extensively used than any other. Creosoted beech ties on the Northern Ry. of France have an average life of 27 years in main track, and then the best of the ties removed in renewing out of face are used in side-tracks seven or eight years longer. On the Houston & Texas Central R. R. 70 per cent of a number of loblolly pine pole ties (natural life six years) laid in the Houston yard in 1874 were still in service after 26 years, the ties which had been taken out having been removed on account of rail cutting. Of 3000 creosoted ties of the same kind of timber placed in the track on the Houston prairie in 1880, 71.6 per cent were still in the track after 17 years, although many of them were more or less badly rail cut. By protecting these with tie plates nearly all were still in service after 22 years. In this track the gravel ballast was filled in to completely cover the ties. These ties were treated with imported material, and the results have been more satisfactory than those obtainable from the use of domestic creosote.

As to the relative merits of dead oil and wood creosote, the former is much the more efficient as an antiseptic and is always preferred in first-class work. Wood creosote is cheaper than dead oil and less dense. The weight of authority seems to establish that wood creosote is soluble in water and that paraffine, its principal constituent, is not an effective preservative of timber. It is usually specified that to exert the best antiseptic qualities, dead oil should contain no water or ammonia, or ingredients soluble in water; that it must be free from tar; that it should be completely liquid at 100 deg. F. According to German authorities, the oils found to be most desirable in oil of tar are those which boil at medium temperatures, as those which boil at low temperatures are too volatile for retention, and also too costly for the purpose, while those which boil at the higher temperatures are too heavy for effective penetration. The latter contain too much solid matter, or substances which harden upon the penetration of the solution into the cooler parts of the interior of the tie, thus obstructing the pores of the wood before its impregnation is complete. It therefore becomes important to remove from the creosote both the lightest and the heaviest oils, in order to retain the medium ones. The weight of the oil at 59 F. may not be less than 8.69 lbs. per gallon.

and not above 9.15 lbs. per gallon; that is, its specific gravity must lie between 1.045 and 1.10. Some of the German railway specifications require that it must not contain to exceed one per cent of lightly volatile oils which boil at a temperature lower than 257 F. Of the remaining constituents at least 75 per cent of the oils shall boil between 455 and 752 F. Twenty-four per cent at the most may boil at temperatures between 302 and 455 F.

Respecting the chief antiseptic property of creosote, experts are not entirely in agreement. The Germans seem to lay great stress upon the component carbolic acid in dead oil; in fact "oil of tar containing carbolic acid" is the term in common usage to denote the article of most approved quality. The specifications of the Prussian State Railways require that at least 10 per cent of the constituents of oil of tar must be oils of the carbolic acid type, dissolving in caustic soda lye of 1.15 specfic gravity. The constituent naphthalene of coal-tar creosote is seldom contained in quantities less than 5 per cent, and sometimes as large as 10 per cent and over, in the original tar, according to the graduation of the temperature in the production of the tar. According to the German view the antiseptic property of naphthalene resides in the fact that after the ties have become cooled it crystallizes and contributes toward the obstruction of the cells, thus preventing the escape of the volatile parts of the creosote and the entrance of moisture and fungi. If present in considerable quantity, however, it may prevent the entrance into the cells of the wood of the heavy oils of the creosote, and for this reason it is desired that the oil of tar shall be "as free as possible from naphthalene," and that, in any event, it be excluded to the point where none shall be precipitated at a temperature of 59 F. If such condition is not obtained the naphthalene will affect the fluidity of the creosote at this temperature. On the other hand some American authorities regard the naphthalene compounds, which occur in commercial dead oil of coal tar to the extent of from 30 to 60 per cent, by weight, as among the most effective constituents of the antiseptic, and consider that carbolic acid is unstable and too volatile at ordinary temperatures to be so classed. Naphthalene is insoluble in cold water, only slightly so in hot water, and at normal temperatures is only slightly volatile. The pyridine and the quinoline series and anthracene are other insoluble and non-volatile compounds that are classed among the most important antiseptic constituents. By way of contrast, the specification for creosoted timber of the Norfolk Creosoting Co. requires that the dead oil of coal tar must be fluid at 118 deg. F., the limits of the specific gravity are 1.015 and 1.05, the yield of naphthalene at a temperature of 410 to 470 deg. F. must be 40 to 60 per cent by volume, and the dead oil must not contain more than 5 per cent of carbolic acid. The specifications of the Southern Pacific Co. require that the material must be completely liquid at 100 deg. F. and contain 20 to 30 per cent of naphthalene.

The quantity of creosote injected is usually 10 to 12 lbs. per cubic foot for pine ties and 16 to 24 lbs. per cu. ft. for pine pile timber. Beech will readily take in 15 lbs. per cu. ft., but oak under similar conditions absorbs only about 4½ lbs. per cu ft. In England Baltic pine ties 5x10 ins.x8 ft. 11 ins. long are injected with 28 to 30 lbs. of creosote, at a cost of 25 to 30 cents each, and last about 16 years under heavy traffic. In France beech and other ties of the most perishable woods are injected with 60 lbs. of creosote, at a cost of about 65 cents per tie, and last 25 to 30 years. In the United States the creosoting process has, on account of its high cost, been applied to tie treatment but very little, although for piling and timbers used in wharves, piers and other structures subject to destruction by marine life it has been used extensively. On bridge timbers creosote is sometimes applied with a brush, three applications being made. The penetration is said to be sufficient to preserve the outer portion of the timber and equalize the life of all parts. For instance, where timber joins timber the fiber about the joint decays much sooner than parts of the timber not in contact. In some cases the caps and sills of trestle bents are preserved, while the posts are not, since the horizontal members are the most difficult of removal in making repairs.

Burnettizing.—The process most extensively employed for treating ties in this country has been the zinc chloride or burnettizing process, so named from Sir William Burnett, the inventor. The first roads to take it up were the Atchison, Topeka & Santa Fe (in 1885); the Union Pacific and the Chicago, Rock Island & Pacific (in 1886); and the Southern Pacific (in 1887). The process consists in subjecting the ties alternately to live steam and vacuum, to liquefy and extract the sap, and then to fill the treating cylinder with the zinc chloride solution and apply pressure to force it into the wood. The zinc-tannin or Wellhouse process is the same with the addition of glue and tannin, explained more in detail further along. The first plant built in this country for working the zinc chloride process was that of the Atchison, Topeka & Santa Fe Ry., at Las Vegas, N. M., in 1885. This plant was at first equipped with two retorts 6 ft. in diam. and 106 ft. long, and in 1896 the plant was enlarged by the addition of a third retort. This plant operates on mountain pine ties costing about 30 cents each. The cost of treatment by the zinc-tannin process has varied, during the years since the plant was built, from 15 to 11.8 cents per tie—for chemicals, fuel, labor and ordinary repairs to plant, interest and depreciation not included. The amount of dry chloride injected has varied, in the different years, from 0.28 to 0.47 lb. per cubic foot of timber. On the Union Pacific R. R. a plant was erected at Laramie, Wyo., in 1886, which was operated about two years, the product of the works being 242,000 ties treated by the zinc-tannin process. This plant had two retorts. It was closed during a period of financial stringency and later burned down and was not rebuilt. The plant of the Chicago Tie Preserving Co., in Chicago, was built in 1886, being equipped at first with two retorts. A third retort was added in 1891 and a fourth in 1894. This plant has been operated mainly on ties used by the Chicago, Rock Island & Pacific Ry. The process worked has been the zinc-tannin, at a contract price of about 16 cents per tie, and the ties treated have been principally hemlock, with some tamarack.

A plant for the Houston & Texas Central R. R. was constructed at Houston, Tex., in 1887, and for some years ties were burnettized at this plant for the Southern Pacific road. In 1891 the Southern Pacific Co. built a plant of its own near Houston, equipped with two cylinders, each 6 ft. in diam. and 112 ft. long, and another 5 ft. diam. and 109 ft. long, open at both ends, with narrow-gage tracks running entirely through the cylinders. At one end of the cylinders there is a yard containing untreated material and at the other end a yard in which the ties are piled after being put through the preserving process. In both yards there are steam traveling derricks. The kinds of wood treated are long-leaf and short-leaf yellow pine, from eastern Texas and western Louisiana, the natural life when used as ties being only three to four years. For preserving ties the chloride of zinc process is used and for bridge ties, timbers and piles the timber is creosoted. This company has also a portable plant, built in 1894, for the Pacific system of the road, which is operated alternately in California and

Oregon, being moved from point to point and set up on side-tracks specially prepared, it being cheaper to move the plant than to transport the ties several hundred miles to and from a stationary one. This outfit is equipped with two cylindrical retorts 6 ft. diam. and 114 ft. long, mounted on car trucks and provided with the necessary auxiliaries, such as boilers for steaming, air pumps, solution tanks, etc.; which are mounted on flat cars, the combined outfit forming a train of about eight cars. The arrangements for setting up the plant are so well planned that the expense of handling is reduced to a minimum. The two cylindrical retorts are run end foremost against a raised platform, so that ties can be run into and out of them on small trucks using a track inside the retort. About 2500 ties, in five charges, can be treated in 24 hours. California mountain pine and spruce, and Oregon fir are the timbers treated. The plant is also adaptive to creosoting either ties or long pile timbers, without any change in apparatus. The entire cost for materials, fuel, labor for operating and ordinary repairs to plant, for burnettizing with this plant has been as low as 8 cents each for soft-wood ties 7x8 ins.x8 ft. A reasonable estimate of the interest charge and an allowance for depreciation of equipment would probably have raised the cost to 10 cents per tie. The cost for burnettizing 6x8-in.x8-ft. yellow pine ties at the Houston plant has been as low as 6.44 cents per tie, for a year's work. The items of this cost were as follows: zinc chloride, 2.54 cents; fuel, 1.04 cents; labor, 2.63 cents; maintenance 0.23 cent.

After the treating of ties was started in this country, in 1885, progress in the development of the industry during the 12 succeeding years was slow, the A., T. & S. F., the C., R. I. & P. and the Southern Pacific being the only roads to take up the work on a considerable scale; but in the five-year period beginning with 1897 the number of plants was largely increased, being built either for, or to be used for, the following roads, at the places named: The Gulf, Colorado & Santa Fe Ry., at Somerville, Tex.; a second plant for the A., T. & S. F. Ry., at Bellemont, Ariz.; the Burlington & Missouri River R. R., at Edgemont, S. Dak., later removed to Sheridan, Wyo.; the Chicago & Eastern Illinois R. R., portable plant; the Great Northern Ry., at Kalispell, Mont.; the Missouri, Kansas & Texas Ry., at Greenville, Tex.; the Chicago, Rock Island & Texas Ry., at Alamogordo, N. Mex.; the Union Pacific R. R., portable plant; the Oregon Short Line R. R., portable plant; the Illinois Central R. R., at Carbondale, Ill.; the Mexican Central Ry., at Aguascalientes, Mex. At the works of the International Creosoting and Construction Co., in Beaumont, Tex., ties have been treated by the Wellhouse process for the Mexican Central and the Hutchinson & Southern (A., T. & S. F. system) roads. It is thus seen that west of Chicago the tie preserving business has become well established. The Southern Pacific, the Atchison, Topeka & Santa Fe, the Burlington & Missouri River and the Illinois Central roads use the straight burnettizing or zinc chloride process and the other roads named use the Wellhouse or zinc-tannin process. The engineers who have been most prominently connected with the development of the Burnett and Wellhouse processes in this country are the late Joseph P. Card, Mr. Octave Chanute and Samuel M. Rowe.

One of the largest tie treating plants in this country is that of the Texas Tie & Lumber Preserving Co., on the Gulf, Colorado & Santa Fe Ry., at Somerville, Tex. This plant was erected in 1897, with four retorts, and later the capacity was increased by two additional retorts and a chloride solution tank. The plant was built for treating ties, piling and other structural timber, and comprises all of the appliances essential for burnettizing and creosoting. On general principles the machinery and its arrangement are the same as in other plants constructed for the same purpose, the similarity in all respects being close except in some minor details, so that a description of this plant and its operation will answer

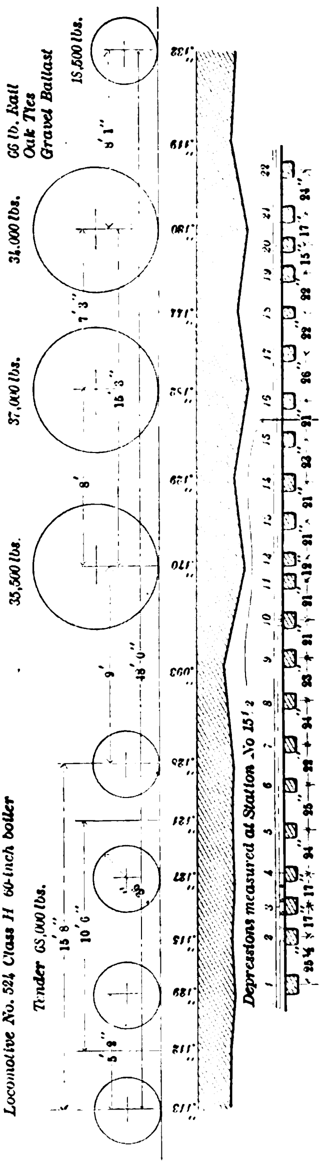


Fig. 476.—Experiments in Track Deflection.

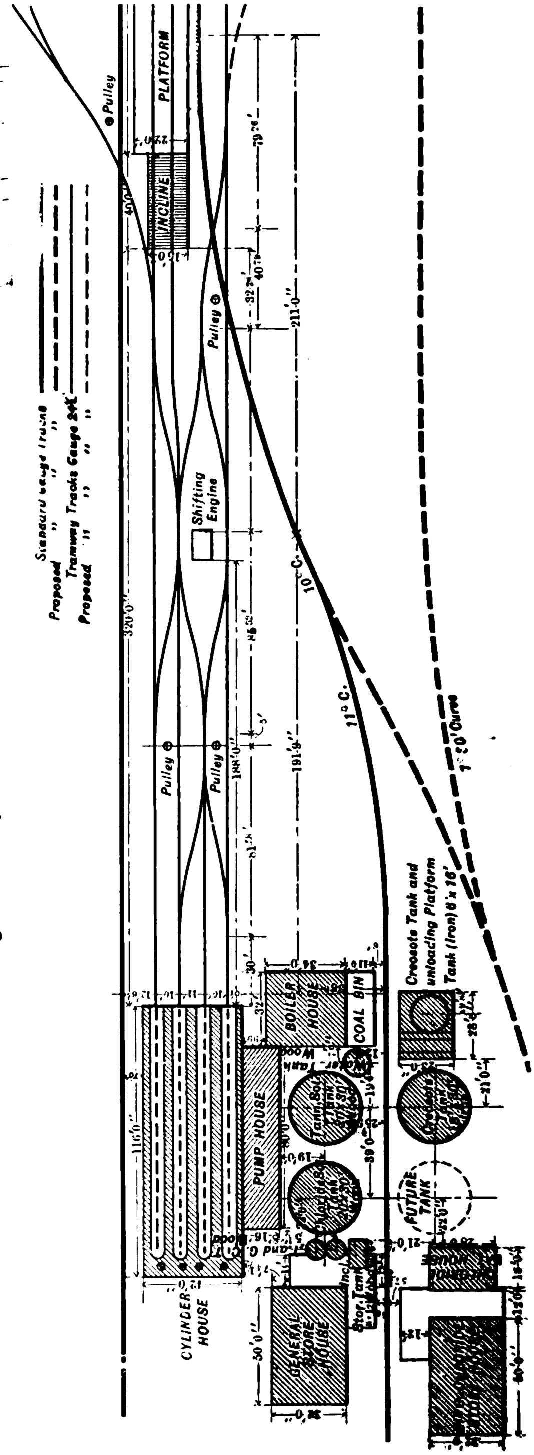


Fig. 477.—Layout of Tie Preserving Plant at Somerville, Tex.

for a typical case. Figure 477 shows the layout of the plant as first constructed, there being a cylinder house, 116x42 ft., containing four treating cylinders or retorts 109 ft. long and 6 ft. diam. Of the six cylinders which the plant now has two are fitted with apparatus necessary to creosote. The two extra cylinders lie adjacent to the four shown, in an addition to the cylinder house, the only rearrangement of the layout being to throw the main side-track farther out from the cylinder house. Adjoining the cylinder house is the pump house, containing the pumps, air compressors and valves admitting liquids to the retorts. For storing the zinc chloride and tannin solutions there are three wood tanks 30 ft. diam. and 20 ft. high, and for storing creosote there is an iron tank 30 ft. diam. and 18 ft. high. There is a general storehouse 50x32 ft., a zinc chloride storehouse 50x32 ft., and a building 18x28 ft. containing vats for mixing the chloride solution.

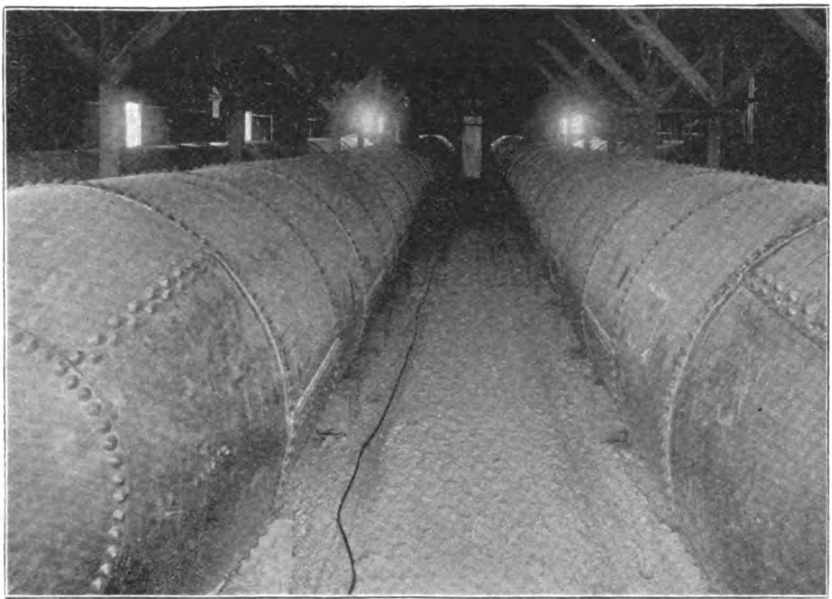


Fig. 478.—Interior of Cylinder House Showing Retorts.

The retorts or treating cylinders (Fig. 478) are made of $^7/_{16}$-in. steel plates in sections 4 ft. 3 ins. long overlapping one another $2\frac{1}{8}$ ins. Each retort has a top dome for admitting compressed air and a bottom dome for the admission of steam and liquids and for drawing off the liquids. Each retort is supported at intervals of 8 ft. $1\frac{5}{8}$ ins. (at the centers of alternate sheets) on oak saddles resting on rollers, so as to give with change in length of the retort due to variation of temperature. Between the ends of each pair of retorts there is a 12x12-in. gate post, and to these posts are hinged the heads for closing the retorts, weighing about 3000 lbs. each. The head is closed down and locked by 24 bars which radiate from the center and operate over fulcrums bearing on the outer rim of the head. The outer end of each of these clamp bars is held down by a staybolt attached to a cast iron flange riveted to the cylinder shell to serve as a seat for the head, and the inner end is attached to a plate backed by a large nut turning on a $3\frac{3}{8}$-in. screw, the head of which bears against the inside face of the retort head. This nut is turned by six spider arms, except for the last few turns in screwing down the head, when a large lever or wrench is employed to tighten it hard against its seat. In Fig. 479, which is a general view of the plant, one of these levers is shown in position on a cylinder head, and the head of the cylinder farthest to the right is shown swung open.

The ties are unloaded from cars run alongside the loading platform,

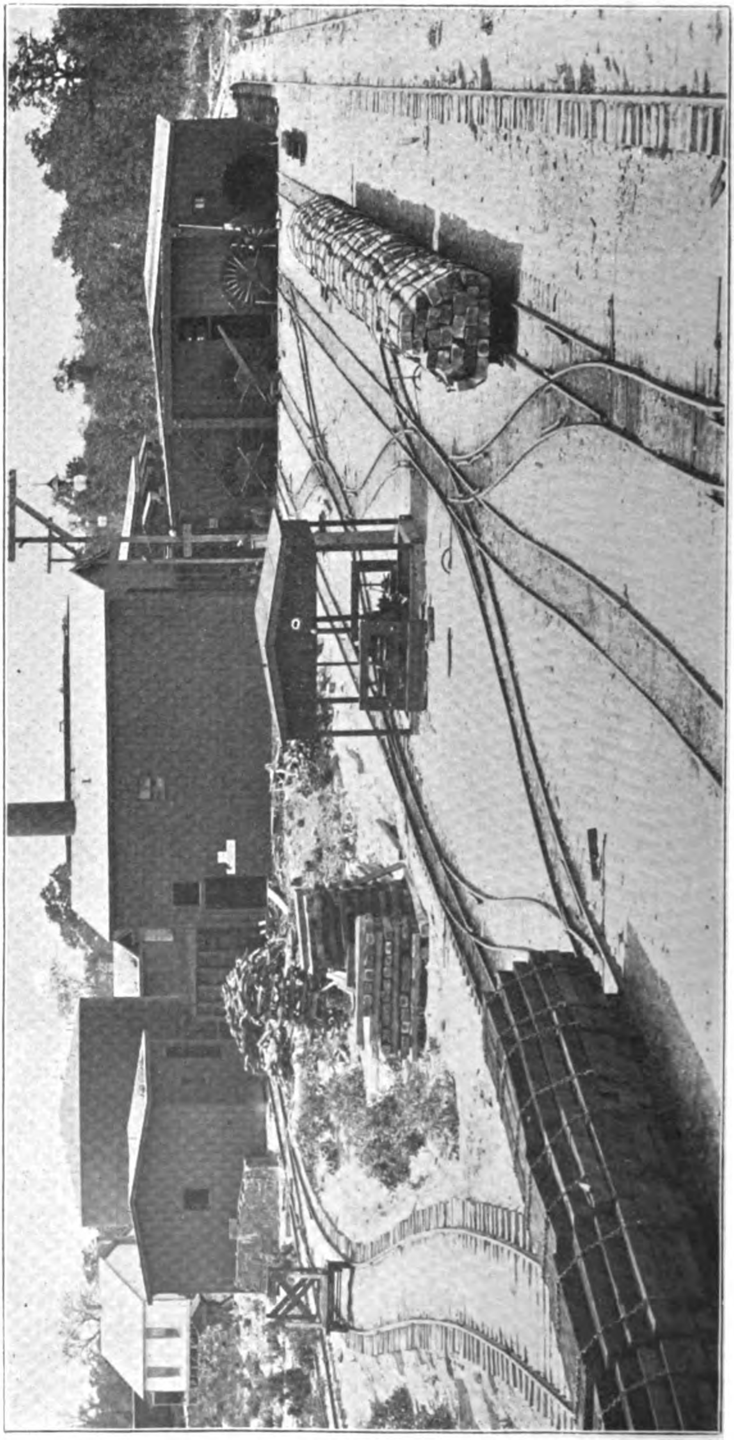


Fig. 479.—General View of Tie Preserving Plant at Somerville, Tex.

and transferred to the tram cars or trucks used in charging. From 25 to 35 ties are bound on each truck, in a cylindrical bunch, by chains, with sticks placed between the layers to give free circulation of the liquids. The trucks for each charge are run together in trains without coupling, so

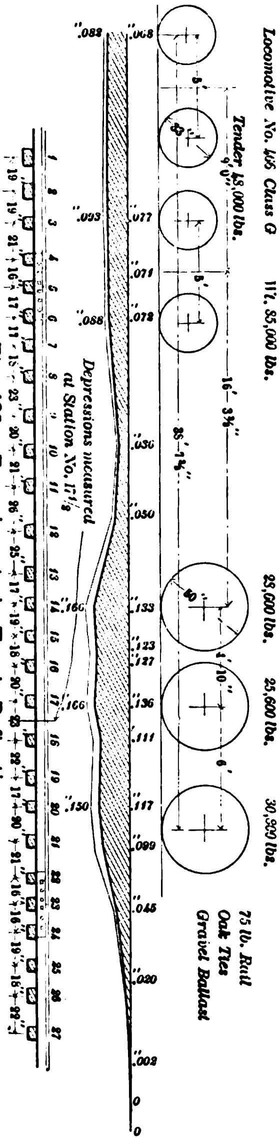


Fig. 480.—Experiments in Track Deflection.

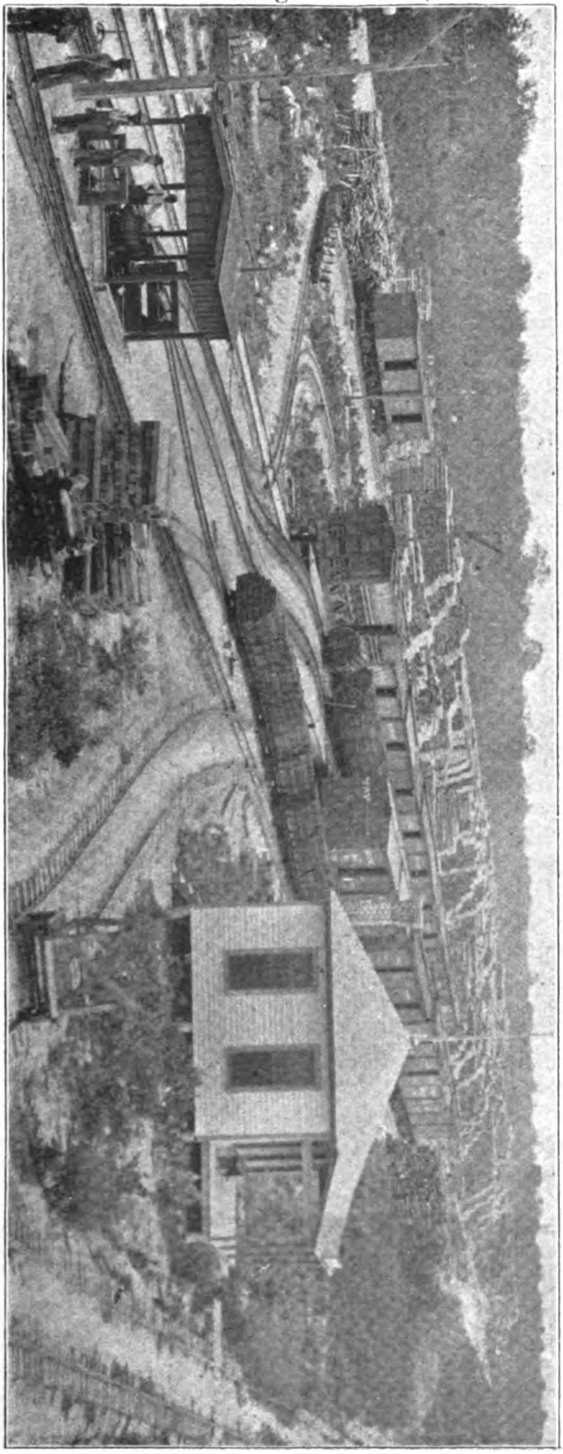


Fig. 481.—Tie Yard and Loading Platform of the Tie Preserving Plant at Somerville, Tex.

as to economize room. A train is run in and out of a retort by means of a cable attached to the hind car, which pushes those in front. The cable is hauled by a shifting engine with a winding drum. One of these engines is located near the cylinder house, as seen in Figs. 477 and 479, and the other (not shown) is at the side of the loading platform, 448 ft. in rear of the one shown. The engine near the cylinder house is used for shifting charges into and out of retorts 1 and 2 (numbered from the pump house), and that in the rear for shifting charges for retorts 3 and 4 and to handle all trains hauled onto the platform. In order to haul a train or charge into a retort the cable must be passed around a pulley at the rear end of the retort, shown in Fig. 477 by a conventional sign; in Fig. 478 the cable so used is seen lying stretched out on the floor. Figure 479 shows at the left a train of ties just taken out of retort No. 4, and at the right a train ready to be run into the same cylinder. The weight of a retort fully charged is 129 tons, of which 38 tons is the empty retort and 91 tons the charge. The latter is made up of 13 cars weighing in the aggregate 5.2 tons, the ties or timbers generally weighing about 35 tons, and the solution about 51 tons.

The gage of the tram tracks is 24½ ins., and where standard gage tracks coincide with the tram lines a third rail is laid. The ties shipped from the plant are run upon a loading platform between two standard-gage side-tracks. This platform is 450 ft. long from the top of the incline, but only one end of it appears in Fig. 477. Figure 481 shows this platform in relation to the tie yard and the various side-tracks and tram tracks.

In some tie preserving plants the first thing in order in the process is to set up a vacuum of 22 to 24 ins. and maintain it for about 10 minutes, to remove the air from the timber and open up the pores. The live steam is then turned in without breaking the vacuum. At the beginning of the treating process at the Somerville plant live steam is admitted as soon as the retort is closed, a 3-in. drain pipe being left open until all of the cold air is expelled; and after that is closed a 1-in. drain is left open while the steaming continues, to carry off the condensation and the sap which flows from the ties. The steam is held at a pressure of 30 to 45 lbs. per sq. in. from two to six hours, depending upon the size of the timber and its condition with respect to seasoning. Large timbers and piling require a longer time to heat through than small sizes. The more dense the timber the longer the time necessary to heat the fiber at the center. The heat of the steam serves to vaporize the liquid sap in the timber, liquefy some constituents of the sap which may have become solidified, and possibly to solidify some of the albumen, which coagulates at 167 deg. F. The steam is finally blown off, either into the atmosphere or into a coil in the creosote tank, in case creosote is being used. Without permitting the retort to cool, a vacuum of about 24 ins., or as near to that as can be, is pumped. This vacuum is obtained by the aid of surface condensers, such assistance to the pumps obviating the difficulty of obtaining a vacuum in the presence of vapor. The vacuum enables the timber to expel the sap and other liquefied matters, which collect at the bottom of the retort and are drained off through the bottom dome in process of pumping the vacuum. The vacuum pump is started as soon as the steam has been blown off sufficiently "to permit the pump to show any gage," in order that the vapor and air in the sap cells may begin their movement out of the timber. "If the retort is allowed to cool," says the manager of the plant, "the timber has a tendency to contract and the cells fill with air, making the work of 'emptying' the timber more difficult.

We find that in doing this we do not have to drain our cylinders after the vacuum, as they are perfectly dry at that time." Without breaking the vacuum the zinc chloride and glue solution is admitted, and as soon as the cylinder is full the pressure pumps are started. The pressure is worked hydraulically, by the solution pumps, and held at 105 lbs. per sq. in. for $1\frac{1}{2}$ hours. It is found, however, that almost all of the solution enters the timber while the pressure is being attained. In the experience at this plant the best results are obtained when the solution is brought to a temperature of about 120 deg., as a cold bath on hot timber does not aid absorption. The timber is allowed to take up all the solution it will. If the amount of pure chloride absorbed is found to be too great the strength of the solution for subsequent charges is weakened. The timber treated is principally southern sap pine, or what is known as loblolly, a small part being long-leaf pine; and it is allowed to absorb .35 to .45 lb. of the pure zinc chloride per cubic foot. After the surplus chloride solution has been forced back into the storage tank a solution of one half of 1 per cent tannin in water is introduced and kept up one hour under a pressure of 80 to 100 lbs. per sq. in. After the tannin solution has been forced out the retort is opened and the ties are run out. The liquids enter the retort by gravity and are forced out by compressed air. As soon as a charge is taken out another stands loaded ready to be taken in. The length of the run varies, of course, with the condition of the timber, but is usually eight to ten hours, and the capacity of the plant is 6000 to 9000 ties treated per day. The number of men employed is 130. The aim is to have all the timber thoroughly seasoned before treatment. The process of injecting creosote into piling or other timber is similar to that of burnettizing, 12 to 15 lbs. of creosote being used per cubic foot.

Zinc chloride is a product resulting from the treatment of metallic zinc with hydrochloric acid (H Cl). It is not manufactured at the plant, however, but is bought in the "fused" or crystal state in sheet iron drums, each containing 1000 lbs. of the salt. At the plant it is dissolved in water in the vats to a solution of about 1.6 to 2 per cent strength and with it is mixed dissolved glue in the proportion of about one half of 1 per cent by weight. In some other plants the glue is kept separate from the zinc chloride solution and is not introduced into the retort until after the chloride solution has been injected and the surplus drawn off. In this plant it has been found more satisfactory to mix the glue with the chloride solution, but arrangements have been made to keep the two separate in case it should be so desired. The creosote is unloaded from barrels (if imported from England) and tank cars and run into an underground tank 16 ft. diam. by 6 ft. high. Here it is heated by coils and pumped into the large tank, where it is again heated by coils to 150 to 175 deg. F. before it is run into the retorts. As creosote partially solidifies at ordinary temperatures, it must be heated in order to be handled, and for this reason it must be steamed by hose to about the consistency of molasses before it can be drawn from the barrels or tank cars.

A modern feature in this plant is the arrangement of the valves controlling the flow of liquids into and out of the retorts and tanks and the admission of compressed air to the retorts. In plants constructed previously to this one these valves were placed at the tanks and retorts, thus necessitating considerable running back and forth to open and shut valves. In this case all valves necessary for the operation of the plant are located in the pump room within easy reach of the engineer. Figure 482 is an interior view of this room. At the left of the room stand the pressure pumps, four in number, and just beyond are the valves which govern the admission of steam into the retorts. Near the center of the room, appearing something like brake shafts on freight cars, are the stems of valves beneath the floor which govern the admission of solutions into the retorts. Just back of these there is an engine and dynamo for lighting purposes. To the left of the engine stands the air compressor, while behind it is the hot well carrying the condensers, to the right of which stands the vacuum pump, not shown in the view. One engineer attends to all the movements. As the plant is operated continuously, both day and night (except 12 hours on Sunday), there are three engineers working eight hours each. The steam enters the bottom dome and is carried to the ends of the retort along the bottom, through coils which pass back and forth three times before the steam is finally exhausted into the open space. The bottom of the retort is in this way heated in advance of the top, and no trouble from strained sheets is experienced when, as is sometimes the case after a retort has been left open for a time, the bottom becomes covered with ice.

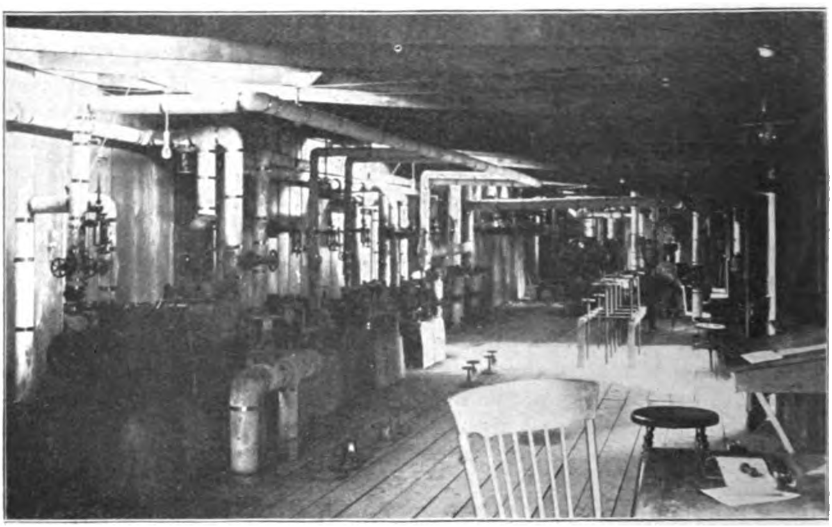


Fig. 482.—Compressor and Valve Room in Pump House.

The portable tie treating plant in service on the Chicago & Eastern Illinois R. R. was built by and is owned by the Chicago Tie Preserving Co. The plant has one retort 6 ft. diam. and 117 ft. long, in two sections, united at the middle by a bolted flange joint. Each 58½-ft. section is mounted on a pair of freight-car trucks, for transportation. As auxiliaries the plant has eight vertical cylindrical steel tanks 9½ ft. diam. and 9½ ft. high, for storage purposes; a steel measuring tank 8 ft. long, 5 ft. wide and 8 ft. high; the necessary air and water pumps, condenser and boilers, of which there are two of 50 h. p. each. There are five wooden storage tanks each 9½ ft. diam. and 9½ ft. high, two lead-lined vats for making the zinc chloride, two tubs for mixing gelatine (glue) and for tannin. There is a platform 320 ft. long and 22 ft. wide, provided with a six-ton scale, and 45 retort cars. The capacity of the plant is about 1000 ties per day. The ties treated at this plant are of water oak, red oak, yellow oak and black oak, having an average natural life of only four years when used for tie timber. The portable plants of the Union Pacific and Oregon Short Line roads are similarly constructed.

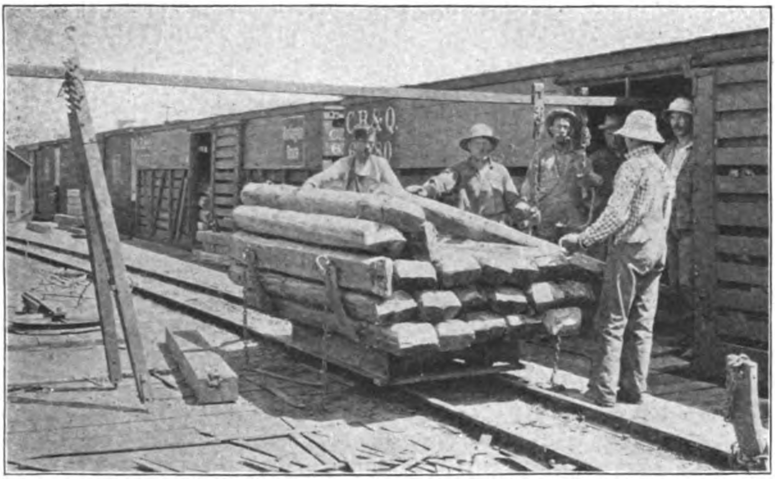


Fig. 482 A.—Angier Tie Loader; View on the Platform.

Fig. 482 B.—Angier Tie Loader; View in the Car.

The weight added to ties by preservative treatment increases materially the labor of handling them, and to reduce as far as possible the fatigue on the men and to expedite the loading of treated ties into box cars, Mr. F. J. Angier, superintendent of the Burlington & Missouri River plant at Sheridan, Wyo., designed a portable trolley arrangement that is set up on the loading platform to extend over and across the loaded tie-treating trucks. The device is used also at the Kalispell works of the Great Northern Ry. It consists of a light trestle leg or A-prop 7 or 8 ft. high, set up on the platform, and a double-rail trolley track running into the car door and branching toward each end of the car. Inside the car this track is supported on hangers clamped to the carlines and hung from the door rail. For carrying the ties there are two L-shaped stirrups, each swung from a trolley wheel by a piece of chain. Each tie handled is placed on the stirrup, at a balance, and steadied by the workman as it is run to place in the car. As the outer end of the trolley track is several inches higher than it is in the car the loaded trolley is moved with but little or no pushing. As the pile of ties gets lower on the truck the chain is let out on the trolley hook to adjust the hight of the stirrup and save lifting the ties. The loader is operated by six men, working at both ends of the car at the same time. The truck from the treating cylinders, holding 30 to 40 ties, is run upon the loading platform opposite the door of the car to be loaded and under the trolley track temporarily set up, as seen in Fig. 482A. Two men lift the ties from the tram car to the carriers. Two men—one for each carrier—push the ties into the cars, and two other men assist the carriers to unload and pile the ties up in place. The sequence of operation is readily understood by reference to Figs. 482A and 482B. A tram truck carrying 30 to 40 ties is unloaded and the ties are stacked up in the car in an average time of five minutes. When rushed, a car of 30 ties has been unloaded and piled up in the car in 1 minute and 50 seconds. The treated ties weigh 200 lbs. and more each, and when the ties were loaded entirely by hand the work required two men to a tie. With the loader six men easily handle 3000 ties in 10 hours. The same work required 10 men before the loader was put into service. The machine is quickly transferred from one car to another, taking but two or three minutes' time.

Regarding the strength of solution most suitable for the treatment there is some difference of opinion. The most general practice seems to favor a solution having a strength of 1.4 to 2 per cent, securing an absorption of one third to four tenths of the volume of the timber, or approximately $\frac{1}{2}$ to $\frac{3}{4}$ of one per cent, by weight, or, more exactly, $\frac{1}{4}$ to $\frac{1}{3}$ lb. per cubic foot, of the pure chloride, for the softer varieties of timber, such as pine. At the Houston plant of the Southern Pacific Co. the strength of the solution is 1.6 per cent, and 6x8-in.x8-ft. yellow pine ties absorb $4\frac{1}{2}$ gals. of the solution or 0.50 to 0.55 per cent, by weight, of the dry chloride salt. While there are many who believe that a stronger solution than stated will injure the fiber of the wood, or that the hygroscopic effect of the excess of salt will keep the timber continually moist, the Chicago Tie Preserving Co. uses a solution as strong as 3.7 to 3.9 per cent, securing an absorption of solution in sufficient quantity to inject $\frac{1}{2}$ lb. of the dry chloride per cubic foot, and no detrimental effects are reported. In Germany a solution of 1.9 to 2.6 per cent strength is considered standard practice. It is the opinion of some authorities who have had long experience with burnettizing that the matter of greatest importance is the thorough absorption of the solution by the timber, and that if such is obtained, a solution as strong as $1\frac{1}{2}$ per cent will give results practically as good as will a stronger solution. The zinc chloride, of itself, should be entirely free from acid, and before applying it to the timber it should be thoroughly stirred or "agitated" in the solution tanks, so that the salts will be evenly dissolved in the water. This is usually done by admitting compressed air through a system of small pipes called the "puddler." Failure to properly mix the solution might result in treating some of the ties with water, or very weak solution, and others with a solution that is too strong. To take up any free acid that may exist in the solution zinc blocks are placed in the mixing vats and solution tanks. In steaming the timber it is generally considered bad practice to use a pressure exceeding 20 lbs. per sq. in., such pressure corresponding to a temperature of 260 deg. F. Some think the temperature should be restricted to 240 deg., corresponding to a pressure of 10 lbs. per sq. in., or to 250 deg. at the outside. The effect of overheating is to make the fibers brittle, and the ties will fail by "shivering" under rail pressure. In practice this manner of failure and the cause thereof are quite well understood.

The amount of absorption in any charge of ties or timber may be obtained from the gage readings of the solution tank before and after treatment. The gage readings of the solution tank before and after filling the empty retort, and again with the empty trucks and wire cable inside (both obtained once for all), and the readings before and after forcing back the surplus solution, give all the data necessary to obtain the displacement or volume of any charge of timber; or, if the pieces are of regular size and shape, it may be obtained roughly by computation. At some plants it is the practice to take the solution from a special, accurately gaged measuring tank, instead of from the main tanks, as soon as the pressure pump is started, and then continue the pumping until a predetermined amount of the solution has been absorbed by the timber. The portable plant in service on the Chicago & Eastern Illinois R. R. is so arranged that each truck-load of ties may be weighed separately, before and after treatment, as the truck is being switched to and from the retort. If any load is found to have taken less solution than the amount determined upon, that truck is switched out of the train and treated again. Of course, the quantity of solution absorbed by a single truck-load can only be estimated, and that in a general way, by comparing the weight with that of other truck-loads, for it is impossible to find how much sap and water has been withdrawn by the steaming and vacuum processes.

In climate of ordinary rainfall or heavier it is found that metallic salts of any kind, being soluble in water, are washed or leached from the ties, thus removing the preservative agent. The Wellhouse process, used in connection with burnettizing, as already noted, consists in injecting into the tie with, or after, the zinc solution, a sufficient quantity of dissolved glue to close the pores, and afterward to inject an extract of hemlock bark known as tannin. The tannin is supposed to change the glue to a tough, insoluble, leathery substance which will occupy the interior of the tie to the exclusion of moisture, and thus prevent the leaching out of the antiseptic materials. The cost of adding the glue and tannin to the zinc chloride process is about two cents per tie. Regarding the practical economy of the Wellhouse or "zinc-tannin" process, conclusive data seem to be wanting. The Southern Pacific Co. and the Burlington & Missouri River R. R. obtain satisfactory results with the zinc chloride process without the addition of the glue and tannin. The life of the ties used on both these roads, however, is favored by a very dry climate, so that, on the real merits of the question, the practice in these cases is not decisive. The constant exposure of the ties to a damp atmosphere and wet ballast is thought to have a worse effect on the stability of the antiseptics than hard rain storms at occasional intervals. The method of applying the glue is also taken into consideration by students of the process. At some plants, as already noted, the chloride solution and glue are mixed together and forced into the timber together, after which the tannin solution is injected to set the glue. In other plants the zinc chloride, glue, and tannin are injected separately, it being believed that the fluidity of the chloride is impaired by the presence of the glue, and that a much better penetration is had by applying the solutions separately. It is also thought that by mixing the chloride and the glue the latter may not become so thoroughly fixed by the tannin, and that organic decomposition of the glue may result. On the other hand, by attempting to force the glue into a tie already fully impregnated with the chloride solution, it is doubtful if deep penetration can be had for the glue. Ties treated by the Wellhouse process require more time for seasoning than when treated by the zinc chloride process proper, which would seem to prove that the treatment has some influence on the passage of moisture through the wood.

Regarding the life of ties treated by the zinc chloride process, in this country, it does not appear that such carefully kept records as will determine the length of service, in all cases, and under all conditions in which the treated ties have been used on various roads, are available. In a general way, however, there is sufficient data of a positive nature to satisfactorily determine the life of special lots of ties treated by this process. The ties used on the Atchison, Topeka & Santa Fe Ry., in Colorado, New Mexico and Arizona are mountain pine, of coarse-grained, knotty, inferior timber, the only kind of timber available except at excessive cost. The life of these ties untreated is four to five years. All of the ties used in renewals since 1885 have been the native pine treated ties. On the Rio Grande division, where the rainfall is light, the average life of the treated ties is 12 years, and the average for seven divisions of the road, for a series of years, has been 11 years and a fraction, or 2½ to 3 times the natural life of the tie. Of the ties treated in 1885, 22.6 per cent were in service after 15 years, and a considerable number were still in the track after 17 years of service, with the prospect that a few would last as long as 20 years. From 1885 to 1889 this road used the Wellhouse process; from 1889 to 1893 the burnettizing process; from 1893 to 1900 the Wellhouse process again, changing back to the burnettizing or plain zinc chloride process in 1900. During the first 15 years of operation the plant at Las Vegas had treated upward of 3¾ million ties.

On the Pacific system of the Southern Pacific road the distribution of the timber supply is such that about three quarters of the mileage can be tied with redwood and other timber but little subject to decay. The remaining 25 per cent of the ties are of mountain pine and other quickly perishable woods which it is the policy of the company to burnettize; and the proportion of treated ties is being gradually increased with that end in view, having reached 21.7 per cent in 1901. In 1902 there were in the tracks of both the Atlantic and Pacific systems of this road 7,569,479 treated ties, of which 82,574 were creosoted and the remainder burnettized. This number constituted about 28 per cent of all ties in service. The average life of the treated ties laid on this road in 1887 was 7.89 years and of those laid in 1888, 9.73 years, but experience has shown that these ties were overheated during treatment, and indications seem favorable to a better showing for the ties treated subsequently. The average life of burnettized ties (principally hemlock, with a few tamarack) on the Chicago, Rock Island & Pacific Ry. has been 11½ years for the lines west of the Missouri river and 10½ years for the lines east of the river. Of 21,850 treated ties laid west of the river 2610 were in service after 15 years, but 1664 were taken out during the following year. On certain sections of the road 28.9 per cent of the treated hemlocks were still in service after 12 years and on other sections 58.8 per cent were in service after 12 years.

From the foregoing records it thus appears that inferior or short-lived timber can, by the application of the zinc chloride or zinc-tannin processes be made to last two to three times the natural life. In order to account for the decay of treated timber the authorities explain that in course of time the salts or other substances injected either undergo a change or disappear by leaching out. It is supposed that decay will take place even in the presence of antiseptics, after the quantity of the same in the timber has fallen below some definite limit. The early decay of a few ties among a lot which generally endure long service may be accounted for in several ways. It is only ordinary experience to find in a quantity of ties of the same kind of timber some which are less thoroughly seasoned than is supposed, and in consequence of different conditions of growth some sticks of timber are closer grained than others of the same species. For one cause or another it is frequently the case that a few ties in a lot otherwise good are so refractory to the standard treatment that an insufficient quantity of the antiseptic is absorbed to thoroughly sterilize the timber. And then, it will frequently occur that a tie in the incipient stage of decay will pass inspection with the defect undiscovered. One point on which experience is conclusive is that the best results are obtained in the arid regions. There is a general belief that both the zinc chloride and zinc-tannin processes harden timber. Neither of these processes corrodes the spikes to an appreciable extent.

The Zinc-Creosote Process.—As creosote is the best timber preservative and zinc chloride only less effective but much cheaper, the plan of combining the two with a view to obtain a result superior to the possibilities of a zinc solution alone, at medium cost, finds a good deal of encouragement, and on some of the German railways it has been practiced to a considerable extent. On the Prussian State Railways the ties are impregnated with an emulsion of zinc chloride and creosote, the latter being in sufficient quantity to effect a distribution of 1¼ lbs. per cubic foot of timber, while the chloride of zinc is present in the usual amount. The results of this treatment are said to be superior to those obtained with zinc chloride alone, and the use of the process in Germany is growing. It is said that by this treatment pine and beech ties are made to last 15 to 18 years, or generally about 25 per cent longer than when treated with zinc chloride alone. The additional cost, over ordinary burnettizing, is about 4 cents per tie. The process as worked in Europe was invented by and has been promoted by Mr. Julius Rutgers, of Berlin. The creosote or dead oil of coal tar required in this work must be light in specific gravity (1.020 to 1.055 at 59 deg. F.), in order to mix readily with the zinc solution, and the proportion of acids of the carbolic acid type is exceedingly high, being 20 to 25 per cent. The carbolic acid contained in the creosote is the only component of the latter which is soluble in chloride of zinc. As, however, the two materials have nearly equal specific gravities they readily form a thorough mechanical mixture.

As such creosote is high-priced there has been some experimenting with zinc chloride and ordinary coal tar creosote applied in separate injections. This is known as the Allardyce process, and as worked at the plant of the International Creosoting & Construction Co., at Beaumont, Tex., it consists of an injection of a 2-per cent solution of chloride of zinc, in quantity equivalent to about 12 lbs. per cu. ft. of timber, followed by a second injection of 3 lbs. of dead oil of coal tar to the cubic foot. The purpose of the comparatively light application of creosote is to form a water-proof coating or shell to close the pores of the wood and prevent the escape of the zinc salts. The first railroad in this country to experiment with the zinc-creosote process was the Chicago & Eastern Illinois, in 1902, the work being done with the portable plant of the Chicago Tie Preserving Co. In that instance 15,000 ties, mainly red oak, black oak and water oak, with, however, some sycamore and other inferior woods, were treated. The solution was mixed and injected to get ½ lb. of zinc chloride (dry salt) and 1.1 lbs. of creosote into the timber, per cubic foot. Tests showed that both the zinc chloride and the creosote oil penetrated the heart of the timber. White and yellow oak ties did not take the treatment as well as the other varieties named. The cost of the process was 6 cents per tie more than that of treating with zinc chloride alone. Further details of this double process, as worked in Europe, and of experience with the same, are given in § 6, Supplementary Notes.

Kyanizing.—In the kyanizing process the timber is boiled or "steeped" in a solution of bichloride of mercury ($Hg\ Cl_2$), commonly known as corrosive sublimate. This is the strongest antiseptic among metallic salts. To properly impregnate timber as large as railway ties requires a treatment lasting eight or ten days. The solution is an active poison and the material must be handled carefully. Where this process is used in Germany the surface of the timber is washed with hot water after treatment, to prevent poisoning cattle or other animals which might lick the efflorescence from the ties. The process was invented by John Howard Kyan, and was applied in England as early as 1832. In this country it was used by the Northern Central and the Boston & Maine roads for treating ties at an early day. The latter road used kyanized hemlock ties for about ten years, beginning in 1882. The strength of the solution was one part of the bichloride to 100 parts of water, by weight. The cost of treatment was 5½ cents per tie and the results are said to have been satisfactory. The eventual increase in the price of hemlock ties and the introduction of cedar ties at low cost led to the abandonment of the process.

In Lowell, Mass., the Locks and Canals Co. has maintained a kyanizing plant since 1848. Except for an interruption of 12 years, 1850 to 1862, the work of treating timber has been carried on pretty steadily. At this plant the steeping is performed in wooden tanks 50x7½ft.x4 ft. deep. Formerly this company (the corporation controlling the water power of the Merrimac river) treated large quantities of timber for its numerous bridges, and a good deal of lumber for buildings, fences and the basement floors of mills in the city. It is said that in and about the old mills and public works of the city there have been found many examples of kyanized pine and spruce lumber practically sound after standing in the ground or being otherwise exposed to the elements for more than 50 years. In Portsmouth, N. H., there are kyanizing works built by the Eastern R. R. (now part of the Boston & Maine R. R.) which have granite masonry treating tanks 60x9½ ft.x6 ft. deep, laid up in cement and coated with coal tar. The capacity of these tanks is 150,000 ft., B. M., of lumber. At these works, during the years 1882 to 1892, the Eastern R. R. kyanized about 800,000 hemlock and tamarack ties, which were put into the tracks all the way from Boston to Portland and also on the branch lines. Some of the kyanized hemlock ties put into the tracks of the Portsmouth & Dover R. R. (now B. & M. R. R.) in 1882 were still in service after 20 years, the timber being in sound condition but badly rail cut and practically worn out. At this plant and the one in Lowell (both operated by Otis Allen & Son) 750,000 to 1,000,000 ft. of lumber, mostly spruce, is kyanized each year. The price for treatment has in some years been $8 per 1000 ft. B. M. A good many ties for street railways have also been treated during late years. The process consists in filling the tank with the ties or lumber and barring it down, and then pumping in the solution (with wooden pumps, on account of the corrosive effect of the solution on iron). The wood is allowed to soak in the solution one day for every inch in thickness of the same. Sawed ties or lumber are separated by laths between the courses, to give room for circulation, but such are not used with hewn ties. In Europe the kyanizing process is worked by four companies.

Boucherizing.—In the Boucherie process the timber is impregnated with a solution of one pound of sulphate of copper ($Cu\ SO_4$) to 100 lbs. of water. The process is used to some extent in Europe, and while the results are satisfactory, as far as increase in the life of the tie is concerned, it is found that the rails and spikes are attacked and seriously corroded by sulphuric acid set free. The process as originally invented by Boucherie, in 1841, consists in injecting the solution into the timber by hydrostatic pressure. After the tree has been felled and cut into logs or into lengths for ties, each piece, with the bark still on, is tilted up and a solution of copper sulphate is applied by fitting a capsule tightly over the end of the log, to which is communicated a pipe containing the solution, which is long enough when standing upright to give the required pressure. The pressure is applied for a variable time, depending upon the absorptive properties of the wood, being about 48 hours for beech and 100 hours for oak. The impregnating solution expels the vegetable sap, which flows off at the lower end of the log, the process being completed when the exuding sap contains a ⅔ part of the solution. Impregnation with copper sulphate is used on the Southern Ry. of France, on the Bavarian State railways, and on the Austrian Southern Ry. As applied on the last-named road the impregnation is effected in ordinary pressure cylinders instead of by the original Boucherie method. Beech ties, which rot in two to three years when untreated, last about 12 years when impregnated with copper sulphate.

Various Processes.—The Thilmany process consists in an injection of either sulphate of copper or sulphate of zinc, with a second injection of chloride of barium. According to the theory of the process a chemical change takes place, the chloride of barium being changed to an insoluble salt which prevents the soluble copper or zinc salt from washing out. Ties treated by this process were at one time used on the Chicago & Alton, the Lake Shore & Michigan Southern, the Erie and the Wabash roads, but the results, so far as reported, are said to have been unsatisfactory.

The Hasselmann process is a chemical treatment intended to produce both a preservative and a hardening effect on the timber. The object aimed at is to effect a combination of the salts injected, to form insoluble products, and also to produce to some extent a chemical combination with the cellulose of the wood fiber. The process (or rather two processes under the same name) is applied in two different ways, one being a double boiling treatment and the other a single boiling. The former consists in boiling the wood in a solution of the sulphates of copper, iron and alumina (the copper and iron sulphates being crystallized together in the proportion of 20 parts of copper to 80 parts of iron), after which the wood is boiled a second time in a solution of chloride of lime and milk of lime (whitewash). The timber is run into a large cylinder or retort, which is then sealed, and immediately a partial vacuum is pumped, when a solution of cuprous sulphate of iron (7 per cent) and sulphate of aluminum (3 per cent) is run into the cylinder and afterwards heated by steam to a temperature of 212 to 284 deg. F., the pressure at the same time being gradually raised to about 40 or 45 lbs. per sq. in. The boiling of the timber in this solution is kept up for two or three hours, when the timber is taken out of the cylinder and permitted to stand for some time, to effect the completion of the chemical action. Meantime, the first solution is used (over and over) on seven or eight different charges of timber—that is, before the first charge of timber is boiled in the second solution. The second boiling of the timber takes place under the same conditions as before, the solution consisting of chloride of lime (1 in 50) and milk of lime (1 in 40). The theory is that the first boiling destroys the germs of fermentation and induces to some extent the chemical union of the preservative with the fiber of the wood, in addition to the formation of insoluble products, as above stated. The second boiling is supposed to harden the wood and render it a non-absorbent of moisture. The whole process, in two intervals, requires about six hours. The single-boiling treatment consists in boiling the wood in a solution of the sulphates of copper, iron and alumina and "kainit," a salt mined at Stassfurt, Germany, consisting chiefly of sulphate of potassa and magnesia and chloride of magnesia. It is claimed that this treatment compares favorably with other methods of timber preservation commonly in use, and so far as the hardening effect is concerned it is represented to be far superior. It is said that fir and beech ties become almost as hard as oak. An important advantage claimed for the process is that green timber can be treated, the unseasoned condition of the wood conducing to a more thorough impregnation of the salts. The process has been used to a considerable extent by the Bavarian State Railways for treating ties. In this country the process is worked by the Barschall Impregnating Co., New York, with a plant at Perth Amboy, N. J.

The creo-resinate process, which is worked by the United States Wood Preserving Co., New York, consists in first vulcanizing the timber and then impregnating it with a solution of 38 parts, by weight, of coal-tar creosote, 60 parts of melted resin and 2 parts of formaldehyde, followed by an application of milk of lime to solidify the resin and creosote oil. One writer has styled the results of the process as "vulcanized wood with an antiseptic shell." The process is intended as an improvement of creosoting, with the following claims for advantages: The vulcanizing of the wood sterilizes it throughout, which cannot be done by straight creosoting except at high cost, and even then it is difficult to penetrate the heart of the timber; the solution is cheaper than creosote; the resin renders the mixture water-proof and protects the sterilized interior against the entrance of fungi spores; the formaldehyde strengthens the antiseptic properties of the compound and restores what is lost in this respect by the adulteration of the creosote. In applying the treatment the timber is run into a retort, when the door is closed and the temperature is raised to 215 deg. F. without pressure, requiring about one hour, and this temperature is held for another hour without pressure, the purpose being to evaporate the moisture. The temperature is then gradually raised under an increasing pressure, to avoid injury to the fiber, until, in the course of two hours, the heat reaches 285 or 290 deg. F. and the pressure 90 lbs. per sq. in., and both are held at this for one hour. For another hour the cylinder is allowed to cool down gradually to 250 deg. and the pressure to reduce to 40 lbs. The pressure and heat are then reduced and a vacuum of 26 ins. is applied, under which the mixture, at a temperature of 175 to 200 deg., is run in and put under a pressure of 200 lbs. per sq. in. by hydraulic means, and held at this until the desired quantity of solution is absorbed. The liquid is then drawn off and the timber is run into another cylinder, where the milk of lime is applied at a temperature of about 150 deg. and at a pressure of 200 lbs. per sq. in. for a half hour. The treating solution weighs 8.9 lbs. per gal., and at 300 deg. the specific gravity is 1.068.

There are a number of patented preservative solutions on the market, represented as having stood the test of years of service, and for which various claims are made. Among the best known of such solutions are woodiline and carbolineum avenarius, the basic principle of each being creosote. The latter material is a mixture of creosote and chlorine gas. The chief claim for these solutions is that their application requires only the soaking of the ties or timber in the heated solution for a short time, it not being necessary that a deep penetration should be had. This simplifies very much the method of application, over those heretofore named. The amount of material absorbed is comparatively small, and the first cost of apparatus very much reduced, as compared with methods requiring the extraction of the sap. An ordinary vat open to the air, with steam coils for heating the solution and a crane for lifting bunches of ties in and out, constitute about all the necessary outfit for applying the solution to the timber. Either solution is also applied, sometimes, with a brush and used as a paint. The Pennsylvania R. R. has used considerable quantities of woodiline for tie treatment, and on the Alabama Midland branch of the Plant System carbolineum avenarius has been applied to ties to some extent. As patented solutions have not yet come into extensive use, and as in some cases their constituent parts are kept secret, an impartial discussion of their merits is not easily undertaken. It is at least fair to say that general experience has not yet proven such simple processes as efficacious as the more thorough methods of treatment involving the extraction of the sap.

There are a few other tie preserving processes and materials that have been experimented with in a small way. In 1902 the Gulf, Colorado & Santa Fe Ry. began experimenting with crude petroleum. The process employed consisted in merely soaking the ties 24 hours in an open vat containing the oil, which came from Beaumont wells. Untreated long-leaf pine ties, average weight 134½ lbs., absorbed an average of 5.67 lbs. of oil per tie. Ties of the same kind of timber previously treated with a 2-per cent solution of zinc chloride, average weight 186 lbs., absorbed an average of 3.49 lbs. of oil per tie. Untreated loblolly pine ties, average weight 124 lbs., absorbed an average of 4.24 lbs. of oil each, and the same kind of timber previously treated with a 2-per cent solution of zinc chloride, average weight 170½ lbs., took up an average of 3.15 lbs. of oil per tie. All the ties were hewn, and, with the exception of the untreated loblolly, had been thoroughly seasoned before soaking in the petroleum; the loblolly had not been as well seasoned as the others. The treated ties were allowed to dry out before soaking in the oil. These ties were laid in an experimental section of track on the Montgomery branch, with a miscellaneous lot of other ties treated with various processes, and are again referred to further along. On bridge ties paint, applied in the ordinary way, has been used by a few roads with results reported to be quite satisfactory. It is perhaps unnecessary to say that ties that are to be painted should first be thoroughly seasoned. Long-leaf yellow pine ties painted with two coats of red oxide of iron and linseed oil, all daps being painted before the ties were placed, were in sound condition after 12 years of service, but had then to be renewed because of rail cutting under heavy traffic.

Mention should be made of various kinds of timber, not hitherto pointed out, that are being treated and used for ties in different parts of the country. The timbers available to the plant of the Great Northern Ry., at Kalispell, Mont., are fir, "bull pine" and large quantities of tamarack, some portion of which is locally known as "mountain tamarack." The timbers treated at the Missouri, Kansas & Texas Ry. plant, at Greenville, Tex., are Texas pine, some post oak and large quantities of sweet gum. The last-named timber is in quality something of the nature of poplar, and in the untreated condition is entirely worthless for any purposes of construction. When treated, however, it renders good service for ties and bridge timber. Some bridge guard rails of this timber treated by the Wellhouse process have stood service longer than 17 years. The timber treated by the Ayer & Lord Tie Co., at Carbondale, Ill. (zinc chloride process), is red oak and black oak. The Atchison, Topeka & Santa Fe Ry. has experimented with treated cottonwood in a small way. These ties began to fail after nine years of service. At the end of 11 years 56 per cent have been removed and at the end of 15 years 86 per cent had been removed. Treated Colorado pine ties began to fail slowly after six years, but after 10 years 66 per cent were still in service and after 15 years 62 per cent were still in the track. In 1901 the Pennsylvania Co. had 16,716 beech ties treated by the Wellhouse process, and during the years 1898 to 1901 the Pittsburg, Cincinnati, Chicago & St. Louis Ry. had 86,956 beech ties treated by the same process. In an experiment with 86 treated Norway pine ties on the Duluth & Iron Range R. R., 92 per cent were still in service after 11 years.

In order to determine the relative merits of various kinds of timber preservatives and processes, as well as the relative durabilities of different kinds of timber treated by the same process, the tie committee of the American Railway Engineering and Maintenance of Way Association, in co-operation with a number of railroads and timber-treating establishments and the United States Department of Agriculture, began, in November, 1901, a practical experiment. With a view to hasten the results of the test as much as possible a region was selected in southern Texas where the climate is favorable to very rapid decay, the annual rainfall and average temperature being high. The place is on the Montgomery branch of the Gulf, Colorado & Santa Fe Ry., near Waukegan, Tex., where untreated pine ties have generally decayed in 12 to 14 months and burnettized ties in two to four years. This experiment was started with 5850 ties of the following kinds of wood: long-leaf, short-leaf and loblolly pine; white, black, red, Spanish and turkey oak; willow oak, hemlock, beech and tamarack. Each kind of wood, generally in lots of 50 or 100 ties each, was treated with five or more of the following processes: zinc chloride (burnettizing), zinc-tannin (Wellhouse), zinc-creosote (Allardyce), with both American and English oils; Hasselmann, crude petroleum, zinc chloride and crude petroleum combined, and spiritine. In addition to this, one lot of ties of each kind of timber was laid untreated, and one lot of 100 red-heart pine ties was treated with the Hasselmann process. The ties were allowed to season several months before laying, and each was marked with three zinc-coated wire record nails stamped to show the date, the kind of timber and the kind of treatment. In the middle of the track the ballast was dressed to cover the tops of the ties.

Experience has taught that only sound timber should be treated, and that most kinds of timber should be thoroughly seasoned before treatment and again after treatment or before the ties are put into service. Unsound wood will absorb a larger quantity of solution than that in sound condition, and if decay has commenced before treatment it cannot be stopped. In Europe the tie-treating contractors exact a discount of 5 per cent from the guarantee to cover "sick" ties, the hidden defects in which cannot be discovered by the usual inspection. Ties treated with the bark on absorb an excessive amount of solution, greatly increasing the cost and giving poor service. A few varieties of timber seem to take treatment best when in the green condition, while most kinds will absorb the solution more satisfactorily after thorough seasoning. At the works of the Chicago Tie Preserving Co. it has been found that hemlock ties improve in receptivity by seasoning, absorbing more of the solution after seasoning than when first received. It has also been found that more sap can be extracted from a partially seasoned hemlock tie than from one freshly cut. To account for this fact it is supposed that when the tie is full of sap it is impossible to heat the interior sufficiently to convert the watery portion of the sap into steam. Hemlock ties cut in summer absorb less than ties of the same timber cut in winter. On the other hand, Oregon fir is said to receive treatment better when green than dry, the phenomenon being explained on the theory that the resin in the wood solidifies upon seasoning, forming obstructions to the penetration of the solution. Timber treated without seasoning usually requires extra work, such as prolongation of the steaming and vacuum and increase of pressure and of the time of applying the same, in order to inject the desired quantity of solution. Nevertheless, at some of the American plants but little heed is paid to the matter of seasoning before treatment. At the Houston plant of the Southern Pacific Co. it has been the practice to treat yellow pine ties felled at all seasons of the year and without regard to seasoning. Ties that have been floated down streams lose more or less of their sap and absorb the treating solution more readily than ties that have not been in the water.

Wood thoroughly seasoned in the air still contains from 16 to 20 per cent of water, and when air-dried wood is exposed for a considerable time to a temperature as high as 277 deg. F. the quantity of water is reduced 75 or 80 per cent. A cubic foot of air-dried white oak weighs about 53.3 lbs. and contains 8.5 lbs. (16 per cent) of water and 44.8 lbs. of fiber. The fiber occupies about 50 per cent of the space, the sap about 10 per cent, and the air which fills the cells not occupied by the sap, about 40 per cent. The specific gravity of wood fiber in all kinds of timber is about 1.5, the variation in weight and density of different kinds of timber being accounted for by the relative amount of space occupied by the cells. Oak and the harder woods, being closer grained, absorb less solution in any process of treatment and are more difficult of penetration, requiring usually a much longer period for the injection of the liquid. In this country chemical treatment of white oak ties has not been practiced to any considerable extent, and as cedar is very durable, so far as rot is concerned, it is not classed among the timbers admitting of economical results from chemical treatment. The timbers selected for treatment are in general the open-grained, porous and sappy varieties of wood, or those which absorb liquids most readily. The amount of solution actually absorbed, however, is sometimes quite variable in the same kind of timber. Thus, at the works of the Chicago Tie Preserving Co. hemlock ties cut in the same place, seasoned in the same way and treated in the same charge, have been known to absorb as low as 13 per cent and as high as 80 per cent, in weight, of the solution.

It is generally conceded that after treatment, ties of any kind of timber, treated with any of the processes, should be loosely piled and thoroughly seasoned before they are put into the track. In the case with burnettized ties the zinc salt is soluble and the water injected with the chloride should evaporate before the tie is inserted in the track, leaving only the salt in the wood; or, if treated by the zinc-tannin process, the leathery pellicles formed by the glue and tannin should have time to dry and harden before the tie is exposed to moisture. Otherwise the moisture in the soil or ballast will begin at once to leach out the zinc salt. In order that the penetration may be thorough where decay is most liable to start some think it advisable to bore the spike holes in the tie before treating and also to do whatever adzing or spotting is necessary at the rail seats. At the old Laramie plant of the Union Pacific R. R. the ties, previous to treating, were run through a special machine which cut them to a uniform length, spotted them for the rail seats and bored the spike holes. Another advantage in boring for spikes is that they can be driven without crushing the fibers of the wood.

In order to secure satisfactory records of the life of treated ties they should be marked in some ineffaceable manner. A means employed in Germany and to a considerable extent in this country is to drive into each tie a galvanized nail with the year of preparation stamped on the head. The date of treatment may also be stamped into the tie, but of course is liable to become effaced by the decay of the timber. In France two dating nails are used—one at the works, when the tie is treated, and another when it is laid in the track.

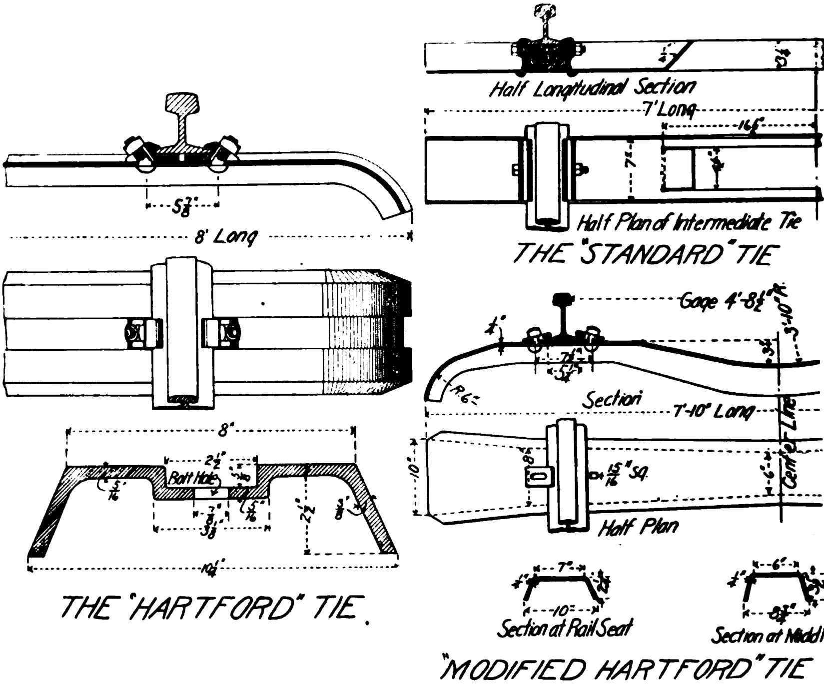


Fig. 483.—American Types of Steel Ties.

In view of the fact that experience with chemically treated ties in Europe has been larger and longer than it has in this country, the particulars and general results of the practice there are both interesting and instructive for comparison with our own practice. An account of this work in Europe is given in Supplementary Notes, § 201. The subject of tree planting by railway companies, as a source of supply for tie timber, is treated as § 202 of Supplementary Notes.

169. Metal Ties.—On the whole, American railroad managers have been slow to seek economy in the use of ties. The chief explanation for this apparent indifference is that our forest areas have been widely distributed, and in most parts of the country an abundant supply of timber has been available at low price. Notwithstanding that this supply has been rapidly vanishing, yet in many quarters where the local forests have become nearly or quite exhausted of tie timber, cheap freight rates, frequently owing to convenience of water transportation, have made it possible to supply the demand from distant sources previously not drawn upon, and at a cost which has been satisfactory. On this account it is easy to see why experiments with substitutes for wooden ties have not been a pressing necessity. As to the use of metal ties in this country there is scarcely no report, for all that has been done has been strictly experimental in character, and that on a scale that is quite insignificant. On this point it will suffice to explain that all the experimental work undertaken with metal ties in this country up to the year 1904 comprised a combined length of less than five miles of track laid with such ties. From the present outlook it would seem that the same tendency will prevail for some time to come, whatever the ultimate result may be, since the attention which is being devoted to frugality in the use of tie timber seems to be leading largely in the direction of tie preservation.

Although the patents issued on metal ties in this country may be numbered by hundreds, only a very few types have succeeded to a trial of any consequence, and an account of the trials on two or three roads will bring out practically all that has been learned about the use of metal ties in this country. In 1889 the New York Central & Hudson River R. R. laid 721 steel ties under 80-lb. rails on a stretch of 1576 ft. of stone-ballasted main track, at Garrison's, N. Y. These ties were of the Hartford type, shown in Fig. 483. This tie, as will be seen, was an inverted trough 8 ft. long, the ends being closed by curving the tie downward about 6 ins. With the exception of the curved ends the tie was straight. The width of the tie face was 8 ins. and the depth 2½ ins., the side flanges spreading to a width of 10½ ins. at the lower edges. The thickness of metal in the face or "top table," as it is called, was $^5/_{16}$ in. and in the flanges, ⅜ in. The tie was of rolled Bessemer steel and there was a channel or groove 2½ ins. wide and ⅝ in. deep along the middle of the top table for the entire length of the tie. The weight of the tie, including fastenings, was 150 lbs. Before laying the ties they were treated with a coating of asphaltum composition applied at a temperature of 300 deg. F. The fastenings for the rail consisted of wedge-shaped clips placed in the channel, and bent bolts ⅞ in. in diameter, passed up through the tie from below. In order to facilitate adjustment of the gage the clip was slotted for the bolt and the bolt was screwed down upon the inclined face of the clip, holding the rail firmly so long as the bolt remained tight. The bolts had the Harvey "grip" thread and no washer or special nut lock was used. At joints the angle bars (6-bolt, 40 ins. long) were notched to allow the clips to engage the rail flange. The ties, including the fastenings, cost $3.11 each. The ballast on which these ties were laid was 24 ins. deep, consisting of a 6-in. bottom course of stones 4 to 6 ins. in diameter and an 18-in. course of rock broken to pass a 2-in. ring. In the filling of the track the ballast was brought level with the tops of the ties and the ballast line was 6½ ft. from the rail. The results with this tie were not entirely satisfactory. Although it made a good showing so far as durability was concerned, it was found difficult to throw the track in line and the expense of keeping the track in surface was about twice the cost of the same maintenance item in an equal length of track laid on wooden ties. The tendency of the ballast was to work away from the tie at the ends, loosening the tie and causing it and the fastenings to rattle while trains were passing, These ties were removed in 1899, after 10 years of service under about 50 trains per day.

In 1896 this company laid 3375 ft. of track with 1350 steel ties at 110th St., New York City. The design of these ties was a modification of the Hartford pattern, as shown at the right in Fig. 483. The tie was pressed from a Bessemer steel (0.10 per cent carbon) plate ¼ in. thick, and resembled an ox yoke in shape. The length was 7 ft. 10 ins. The ends were turned down and the middle portion curved downward 3 ins. to a radius of 3 ft. 10 ins. The width of the tie face at the middle was 6 ins.

and at the rail seat 7 ins. The bottom width at the middle was $8\frac{3}{4}$ ins. and at the rail seat 10 ins. The depth of the tie at the middle was $3\frac{1}{2}$ ins., and at the rail seat $2\frac{1}{4}$ ins. The rail was fastened with wedge-shaped clips and $\frac{7}{8}$-in. bolts, as in the original design. The weight of the tie, including fastenings, was 100 lbs. and the cost was $2.50. In filling the track the curved portion at the middle of the tie was covered with ballast. These ties gave less satisfaction than those of the older design in use at Garrison's, being hard to throw in line and less able to stand the crushing weight of trains, in consequence of which they failed by crushing under the rail and by breaking in the middle. They were removed in 1899, after being in service three years under a traffic of 250 trains per day.

The "Standard" tie, shown at the upper right hand in Fig. 483, was of plain channel section, stamped from a steel plate $\frac{1}{4}$ in. thick, and was laid open side up. The side flanges of the channel were vertical and $3\frac{1}{4}$ ins. deep, and the ends of the tie were open. The tie was 7 ft. long and 7 ins. wide, except in the case of joint ties, which were 10 ins. wide. As will be seen in the illustration, a portion of the bottom of the channel at the middle of the tie was cut out, leaving an open space. The part cut out was $4\frac{1}{2}$ ins. wide and 24 ins. long, but the bottom was actually cut loose for a length of 33 ins., so that a flap-like piece $4\frac{1}{2}$ ins. long remained at each end of the opening and was bent upward at an angle of 45 deg., so as to offer resistance to lateral motion, the tie being filled with ballast. The rail was supported upon a block of creosoted oak wood fitted into the channel. This block was $2\frac{5}{8}$ ins. deep and sustained its load endwise the grain. The rail was supported entirely by the block, the sides of the tie being cut away to a depth of $\frac{1}{2}$ in. (thus weakening the tie at the point of greatest bending moment) to make room for the rail flange. The fastening for each rail consisted of two Z-shaped clamps, the upper clasp of each clamp engaging with the rail flange and the two claws forming the lower projection of the clamp engaging the bottom of the tie through holes. On intermediate ties the clamps were held to their engagement with the rail by one $\frac{3}{4}$-in. bolt passing horizontally through the clamps and the wooden block, while at joint ties two bolts were used. The intermediate ties weighed 82 lbs. and cost $2.50 each; the joint ties weighed 105 lbs. each and cost $3.50.

In October, 1889, a stretch of 1000 ft. of main track on the Chicago & Western Indiana R. R., at 69th street, Chicago, was laid with "Standard" ties spaced $23\frac{1}{3}$ ins. centers. The ties were ballasted with gravel; the joints were spliced with plain fish plates (angle bars could not be used owing to the interference between the horizontal leg of the bar and the tie clamp); the rails were laid with square joints, supported. The traffic over these ties was heavy, amounting to about 80 trains per day, all in one direction. After some five or six years of service it was found necessary to replace the ties at the joints with wooden ones, but the intermediate ties remained in the track until the spring of 1899, when all were removed. The condition of the ties at the time of removal would lead one to think that they had reached the full limit of their usefulness. They were badly corroded, the flanges in some cases being reduced to the thickness of a knife blade, and many of the ties were cracked or broken at the rail seat. The oak blocking at the rail seat was in much better condition than the metal portion of the tie, being practically as sound as new timber.

The Standard tie was tried on several other roads but in no case did it remain as long in service as on the Chicago & Western Indiana R. R. In 1890 about $\frac{3}{4}$ mile of track on the Delaware & Hudson R. R., near Saratoga Springs, N. Y., was laid with these ties, but they were found to be unsatisfactory and were taken out after a year's service. The ballast in which the ties were laid was fine gravel, and the difficulty seems to have been in keeping the track to surface. The Long Island R. R. laid 500 Standard steel ties, 16 ties to a rail length of 30 ft., and these ties remained in service three years under a traffic of 130 trains per day, except the joint ties, which were removed at the end of 18 months and replaced with wooden ties. It was found difficult to keep the track in line on curves and the use of fish plates at the joints, instead of angle bars, made it difficult to hold the joints to surface. During the three years in which these ties were in service the cost of maintenance exceeded the usual cost of maintenance for track laid on wooden ties by about 30 per cent. Another experiment with the Standard tie was tried on the Philadelphia & Reading Ry., ¾ mile of main track in Philadelphia being laid with these ties in the summer of 1891. The track was laid with 80-lb. rails, in slag ballast, and the traffic averaged about 260 trains per day. It was found that the ties worked up and down in the ballast and it became difficult to keep the track in line and surface.

In the designing of all or nearly all the metal ties which have been experimented with to any extent, economy of material has been the principal aim rather than the production of a tie properly shaped for the conditions which it must meet in service. This statement is made with the full understanding that thousands of miles of track laid with metal ties are now in service in foreign countries, with evident satisfaction. The type of tie which appears to meet with most favor abroad is a tie of trough section, laid open side downward, and not departing widely in principle from the Hartford tie, which was tried on the New York Central R. R. Notwithstanding this fact it is doubtful if any tie of this pattern can satisfactorily fulfill the maintenance requirements of the railroads of this country, considering the weight of our rolling stock and the climatic conditions prevailing. In attempting to distribute a minimum quantity of metal to obtain the required stiffness, the tie of trough section seems to respond most readily to this one requirement, but it is the worst possible form of tie for the operations of track surfacing. Granting that the tie will eventually settle itself into the ballast until a compact bed is formed, the difficulty is found in tamping such a tie with any degree of facility and effectiveness when low portions of the track must be raised and surfaced. Suppose that a tie is raised an inch or such matter and the ballast is to be tamped up to hold the tie. As it would be impossible to force the ballast into the crescent-shaped cavity next the tie surface, with either a tamping bar, tamping pick, or any other tool known to the occupation of a trackman, it becomes necessary to break up the core of material filling the entire cavity on the under side of the tie, thereby destroying its compactness, which is the essential quality required to hold the tie in its raised position. While it is true that in the use of the tamping pick in stone ballast, in a small lift, it becomes necessary to break up the old bed to some extent in order to tamp the tie, nevertheless such disturbance does not extend to any considerable depth into the ballast, and the force of the pick is exerted against a layer of material in immediate contact with the bottom face of the tie—which cannot be the case in tamping a tie of trough section. During the early months of 1901 the Bess. & Lake Erie R. R. laid 2135 ft. of main track with steel ties, near Osgood, Pa. These are of inverted trough section, with flaring sides, top face 5 ins. wide and the sides 3½ ins. deep. The ties weigh 208 lbs. each. Fully realizing the difficulty of properly tamping them with the customary tools, use has been made of air-blast apparatus, consisting of a No. 3 Root blower clamped to the rail and turned by two hand cranks. The ballast is slag and tamping is done by raising the ties and blowing pulverized or finely broken slag under them. Figure 483A shows a stretch of this steel-tied track, with the air-blast machine in position for service. Some details of the design and operation of air tamping machinery are given in § 85. The use of the same with wooden ties, where the conditions are most favorable to its operation, has been only experimental.

The tie of ideal shape, and, in fact, the only one which can properly perform the functions of a tie, is one having a flat bottom easily accessible for tamping, and the under face of the tie should be straight. If the tie dips in the middle a cavity is formed in the ballast to collect and hold water, to be churned by the trains; and whether the middle of the tie be curved downward or upward, the uneven bed must form a serious obstruction to the work of throwing the track to its proper alignment from time to time. To do good service a tie should also have depth, for if there be not a considerable depth of filling between the ties the layer of ballast immediately adjoining the bottom face of the tie, especially after the tie

Fig. 483A—Air Blast Apparatus for Tamping Track, B. & L. E. R. R.

has been newly tamped, is easily shaken out of place by the action of moving trains. Depth of tie is also required in order to obtain the necessary stiffness, but the scheme of deepening the tie and forming it of thicker metal calls, of course, for more material, and the additional metal required may encroach upon the margin of cost which decides the economy of the metal tie. It is perhaps but a truism to propose that a metal tie with a flat, straight bottom face and with depth and stiffness equivalent to these features of the wooden tie, would serve as well as the wooden tie for a track support; and such requirements will probably have to be met before the metal tie can successfully cope with the conditions which obtain on American railroads. That the tie should contain but few parts and be so designed that it can be produced with but little hand labor goes almost without saying.

Of the commercial shapes the T-bar and the I-beam seem best adapted to the requirements of a metal tie, as the desired stiffness can be obtained with a moderate weight of metal and the bottom face of the tie is of the right shape to properly support the track and admit of tamping by practicable means. The Bidwell steel tie is designed as an inverted T-section, to be rolled from soft steel, with a base 8 ins. wide and $\frac{3}{8}$ in. thick and a vertical leg of the same thickness and 4 ins. high. The support for the rail consists of a plate bent into the shape of a "U" and inverted over the vertical leg and riveted to the bottom leg. The vertical leg of the tie is notched for the rail seat, and the fastening consists of a lip in the top edge of this leg, for one side of the rail flange, and a clasp attached to the vertical leg, on the other side. A section of track in the Kansas City yards of the Chicago & Alton Ry. was laid with these ties in 1897, the T-shape being formed by riveting together two angle bars. The Chester steel tie, laid experimentally on the Huntingdon & Broad Top Mountain R. R., at Huntingdon, Pa., in 1899, consists of three separable parts, being composed of an inverted steel T-bar 6 ft. long, reinforced by a section of inverted trough placed transversely at either end to afford extra bearing and support for the rail. The horizontal leg or bottom of the T-bar is 4 ins. wide and the vertical leg 3 ins. high, the latter being mortised for rail seats at the proper gage, while the trough-shaped base pieces are slotted to hold firmly to the T-bar and in a manner to form the rail seat; or, in other words, the T-bar extends through a slot in each leg of the inverted-trough base pieces. Each base piece has two lugs struck up to engage and clamp the inner flange of the rail, and the mortise or notch in the vertical leg of the T-bar is cut under so as to form a hook or projecting clip to clamp the outer flange of the rail. This notching of the T-bar prevents the rail from being crowded out of gage, either outward or inward. The rails are thus attached to the ties without a bolt, wedge, clip, pin or other loose fastening. The thickness of metal in the T-bar is $\frac{3}{8}$-in. and each base piece is 10 ins. long and 10 ins. wide, with depending flanges 5 ins. deep, the thickness of the metal being $\frac{3}{8}$ in. The weight of the T-bar is 53 lbs. and the total weight of the tie is 90 lbs. The Bidwell steel tie was illustrated and described in the Railway and Engineering Review of March 25, 1899, and the Chester steel tie in the issue of Dec. 30, 1899, where further details are to be found.

The I-beam principle of steel tie design has been applied by Roadmaster C. Buhrer, of the Lake Shore & Michigan Southern Ry. The original idea with Mr. Buhrer was to utilize scrap material exclusively by rerolling old rails, the head of the rail to be spread out into a flange 8 ins. wide, to form the bottom face of a tie somewhat shallower than the original rail section. Facilities for rerolling rails in this manner were not, however, in commercial use, and some question was raised as to whether such a shape could be cheaply rolled. When it came to the question of providing ties for an experiment, the quantity not being large enough to induce the mill people to roll them to shape out of old rails, the bottom face of the tie was formed by riveting a steel plate to the head of the old rail. The tie was then inverted, the base of the old rail serving as the top face of the tie. The fastening devised was simple and secure, consisting of ordinary clips held by bolts passed through the upper flange from below. To assist in holding the tie in alignment, or from shifting longitudinally on its bed, depressions were made in the lower flange, under each rail seat. In the spring of 1901 a stretch of 300 ft. of track was laid with ties $8\frac{1}{2}$ ft. long made in this manner. The location is on a curve about $2\frac{1}{2}$ miles east of Sandusky, O., where all the trains run at a high rate of speed. The ties were made of 65-lb. scrap steel rails and were laid at 2 ft. centers to replace wooden ties 7 ins. thick. The steel ties being only $4\frac{1}{2}$ ins. deep, the work of tamping the new bed was carefully done, but after that no particular attention was given to them. These ties have held the rails in good gage, alignment and surface, and, so far as service is concerned, they have given excellent satisfaction. Being shallower, they are tamped with less labor in digging out the ballast than is required for wooden ties, and as the bottom face is wide and flat the work of tamping has been just as efficient in holding the surface as it is with wooden ties. These ties admit of nearly, if not quite, as much flexibility of use as wooden ties. They can be put into the track as cheaply as wooden ties, and they can be used promiscuously to replace decayed wooden ones, tie for tie, in the same manner that wooden ties are placed in renewals. It is not necessary to lay them out of face. On these ties a rail can be exchanged or the rails can be shimmed in winter, as readily as on wooden ties.

If the cost of ties made by utilizing the material of worn-out rails could be kept within an economical limit the proposition would certainly be enticing. The weight of this tie is one of the chief points of criticism. If made 8 ft. long, from an old 65-lb. rail, the weight would be about 160 lbs. Of course it is to be considered that the scrap value of the tie when worn out and removed from the track would be an important item. The quantity of metal then available would be the original weight less only that lost by corrosion. Taking one year with another, the value of scrap rails to a railway company is quite variable. In past years there have been times when 160 lbs. of scrap rail metal would not net the railway company more than 80 cents. At 4 per cent the annual interest charge on the material in each tie, at this value, would be only 3.2 cents, which would be quite reasonable, but the average price of scrap rail steel is higher than the figure stated, and in making cost comparisons with ties of different design or of lighter weight the expense of transporting the material to and from the mills, the cost of rerolling, and the final loss by corrosion in the track (which might be little or much, according to the character of the soil or of the ballast) should be taken into consideration. Without actually attempting to reroll the old rails into ties, estimates on that item would, of course, be only speculative. The excellent service which the experimental steel ties have given on the L. S. & M. S. Ry. suggests that the design is worthy of careful investigation. It might be that old rails of considerably lighter weight than 65 lbs. per yd. could be worked over into ties of sufficient strength, or it might be found that the ties could be rolled direct from new metal at an economical figure.

Composite Steel and Concrete Ties.—The cheap cost of concrete and its durability have been taken into account in the study of substitutes for wooden ties, and experiments with this material have been undertaken on several roads. The general idea is that the concrete should be reinforced with a steel member or framework of some kind, more especially to prevent breakage from center binding or heaving, and to hold the material together in case of fracture or breakage, thus securing the gage. So far as direct compressive stress is concerned the concrete is regarded to be reliable. About the first experiment in this direction was made in Chicago, with some ties designed by Mr. J. J Harrell and put into the main track of the Pittsburg, Ft. Wayne & Chicago Ry., near the Union station, in the summer of 1899. The design consisted of concrete molded around a truss of 1-in. rods, put together on the style of a trussed pipe brake beam. The ties were 7 ft. 4 ins. long, 8½ ins. deep under the rails, 10 ins. wide on bottom under the rail seats and 6 ins. wide on bottom under the middle portion of the tie. The ties were 30 in number laid under 85-lb. rails in broken stone ballast, on a curve of 6½ deg. The traffic over the ties was very heavy, consisting of the east-bound passenger trains of the road named and all the west-bound passenger trains of the Chicago, Burlington & Quincy and the Chicago & Alton roads. Although it became apparent quite early that the life of these ties would be short, they nevertheless outdid the expectations of some by lasting 17 months before they were removed from the track, and the experiment was instructive. Two or three of the ties cracked transversely at the middle, the appearances indicating that they had become center-bound and were unable to stand up under the loads. The greatest difficulty, however, was with the fastenings, which consisted of bolts set in the concrete, with ordinary clips for holding the base of the rail. These bolts became loose in the concrete and the side thrust and working of the rail shattered the material under the rail seats, which consisted of a steel plate embedded in the concrete.

Encouraged by this experience Mr. Harrell redesigned the tie on improved lines. In the later pattern the metallic core or frame consists of a steel web plate $\frac{1}{4}$ in. thick, 7 ins. deep and 7 ft. 8 ins. long. The upper corner of each end of this plate is slitted and lopped over each way. The plate is also perforated at frequent intervals by punching out square holes and bending over the tongue of metal, to give the frame a firm hold in the concrete. The bearing for the rail consists of a plate 5 ins. wide, 14 ins. long and $\frac{3}{8}$ in. thick, resting upon the top of the steel web and upon the concrete. The fastening for each rail consists of a pair of straps riveted to the web plate and projecting up through the tie plate or rail seat. The rail is held to the plate by spring links which straddle the straps and are held in place by common track spikes run through slots in the straps after springing the links down with a bar. The tie is 8 ft. long, over all, and $8\frac{5}{8}$ ins. deep. Each end of the tie, for about one-third of its length, is 9 ins. wide on bottom and 5 ins. wide on top. The middle third of the tie is 5 ins. thick, and the bottom corners of this portion are rounded, to restrict the bearing surface and prevent center-binding. The tie weighs about 300 lbs., of which 55 lbs. is metal. The concrete is made of crushed limestone and Portland cement in a very wet mixture. The proportion of the materials is the result of a good deal of experimenting, and it differs materially from that of concrete for ordinary building construction, in that no sand is used. The stone for the mixture is "crusher run" of $\frac{5}{8}$ in. size and smaller, no attempt being made to separate the dust, which was found to produce a stronger concrete than could be made by the use of sand. Some of these ties are laid in a side-track of the Pennsylvania Lines, at Hegewisch, Ill.

In 1901 the Pere Marquette R. R. began experimenting with a composite tie of concrete and steel construction designed by Mr. Geo. H. Kimball, at that time chief engineer. The tie consists of two bearing blocks of concrete each 3 ft. long and shaped like a pole tie. Each of these blocks is 7 ins. deep and the face is 9 ins. wide. Each pair of concrete blocks is joined by two 3-in. channels placed 2 ins. apart, back to back, and molded in with the concrete. The general arrangement and details are illustrated in Fig. 484. The bearing of the rail is taken by a 4x9-in. white oak cushion block 18 ins. long. This block is secured to the concrete base by $\frac{1}{2}$-in. square bolts molded into the concrete block and jointed at the top surface thereof by means of a screw socket. The top head of the bolt is countersunk into the wood and the space around the same is filled with pitch, to exclude water. The wooden blocks are treated with carbolineum. To these blocks the rail is spiked in the usual manner, but the use of clips, as shown at the left of the middle engraving, has been considered. In places where a wooden block is used that is thinner than the length of the spike, elm plugs are molded into the concrete block and bored for the spikes. Against the outside end of each oak block there is a concrete shoulder, to prevent spreading of the gage should the block become loose. The method of connecting the anchor bolts to the channels is made clear in the sectional view. The pin for this connection projects into the concrete about one inch from the side of the channel, thus giving the channel a secure hold in the masonry. The exposed surface of the channels, between the concrete blocks, is protected by two coats of Portland cement mortar spread on thin, and to further protect the steel from corrosive action the space between the channels is filled with concrete. The concrete in the bearing blocks consists of two parts of Portland cement, one part sand and three parts of ¾-in. screened gravel. The blocks are molded to the ends of the channels under a pressure of 10 lbs. per square inch. The weight of the tie is about 452 lbs., including 68 lbs. of metal, 374 lbs. of concrete and 10 lbs. of wood block, and the cost was $1.46 each, including 50 cents for concrete and labor of molding. In 1902 three quarters of a mile of track in Jefferson St., Bay City, Mich., was laid with ties of this design without the channel bars. The Pere Marquette R. R. enters Bay City by this route, and as the street is paved, special construction of a permanent character was desirable. The ties were laid in cement mortar upon a bed of concrete 9 ins. deep, being set to a true grade with an engineer's level, and after the track had been put to surface the space between the ties up to the level of base of rail, was filled in with concrete. On this was placed a 1-in. bedding for the paving blocks. As the concrete ties or (properly speaking) supporting blocks abut against the foundation of the pavement, it is impossible for them to become separated or spread farther apart, and the steel channels were therefore omitted. The oak cushion blocks were the only perishable material used, and they are renewable.

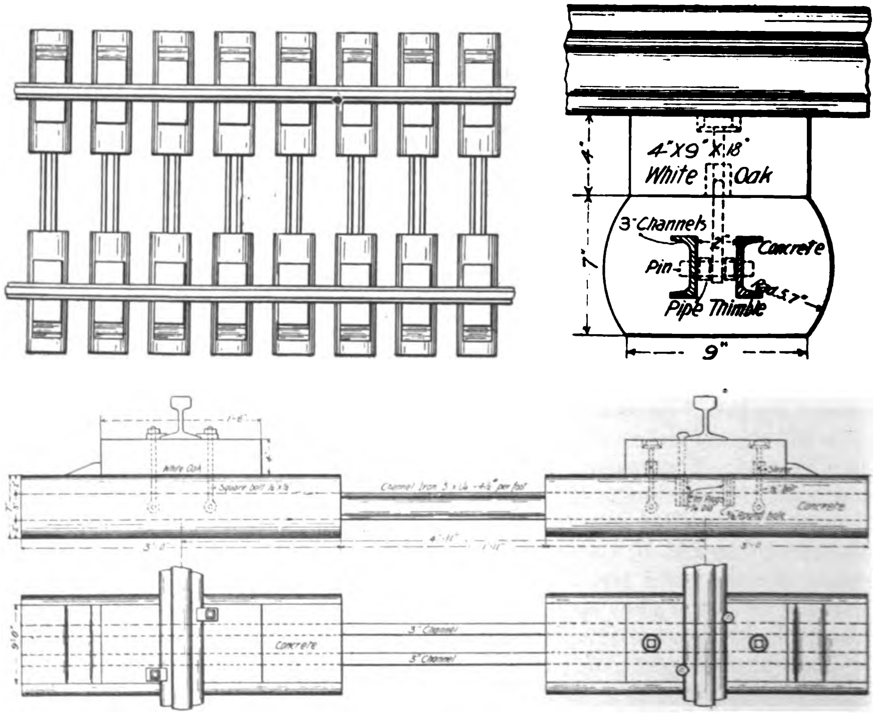


Fig. 484.—Kimball Composite Steel and Concrete Tie, Pere Marquette R. R.

Another idea applied in composite tie construction is to place a stiff steel member in the top of the tie, to take the bearing of the rails and hold the fastenings. The body of the tie then consists of concrete molded to the under part of this top member. This design is the invention of Roadmaster C. Buhrer, of the Lake Shore & Michigan Southern Ry., and in the spring of 1902 a number of ties so constructed were laid in the main track of that road, near Sandusky, O. These ties were made by molding a concrete body or base to the head of an inverted piece of old 65-lb. rail, but for economy of metal a lighter rail might be used, or an I-beam or other shape of lighter section might be found to answer the purpose. The first ties put into service are 5½ ins. deep and 8 ins. wide on the under face, except at the central portion, which is narrower, so as to avoid full bearing and liability to center-binding. The fastenings consist of bolts and clips applied to the upturned base of the rail, as is done with the Buhrer steel tie. Buhrer composite ties of later design are 6½ ins. deep and 8 ins. wide on the bottom face. Trial sections of main track have been laid with these ties on the L. S. & M. S. Ry., at many points; on the Chicago & Northwestern Ry., at Milwaukee; on the Lakeside & Marblehead R. R., at Danbury, Ohio, and on other roads mentionel in § 210, Supplementary Notes.

The Adriatic Ry., in Italy, is using a number of concrete-steel ties, the cross section of which is like a triangle with the corners cut off. The ties are 8.53 ft. long, the bottom width is 7.87 ins., and at the rail seats the top face widens out to the full bottom width. The concrete consists of a mixture of cement and sand in the proportion of 121 to 165. The reinforcement consists of 28 round steel rods running straight through the tie longitudinally. The aggregate cross-sectional area of these rods is 3 sq. ins., and they are distributed (as seen sectionally) in two horizontal rows, near the bottom face of the tie, and in three rows vertically along the middle part of the tie; in other words, the general shape of the reinforcement is like an inverted "T." Each tie weighs 287 lbs., including 88 lbs. of metal, and the cost ranged from $2.16 to $2.40.

One question which arises in connection with the use of concrete for tie material is the effect of derailments. It is not an uncommon occurrence for the wheels of freight cars to become derailed and run over the ties for several miles before the accident is discovered. In such cases wooden ties, although cut by the wheel flanges, are not usually rendered unfit for service, but the ties get severely bumped, and it is a question whether ties with exposed concrete in the top face would not be shattered or broken up by such rough treatment. In the Buhrer composite tie the top face of steel seems well designed to protect the concrete in case of derailment.

Although it seems unlikely that the day for the general introduction of metal ties in this country is near at hand, yet industrial conditions are continually changing, and the possibilities in the field certainly suggest the wisdom of careful study and experimentation along such lines. One serious obstacle to the general use of an all-metal tie would be found in the difficulty of insulating the rails for the track circuits of automatic electric block signals, which have been extensively adopted on American railroads. In such signal systems track circuits are much preferred to wire circuits. Possibly some means of overcoming this difficulty could be found, and the problem invites careful study. The solution might be found to satisfaction in some form of composite tie. The Kimball tie of the Pere Marquette R. R. (Fig. 484) insulates the rails. The experience with metal ties in foreign countries, in some of which they have been used extensively, is treated at some length in § 203, Supplementary Notes.

170. Lag Screws vs. Spikes.—Every now and then some ingenious man, casting about for opportunity to work an improvement in track construction, hits upon the track spike and finds something to say condemnatory of its use. It is a fact, however, that the shortcomings of the spike as a track fastening, such as they are, were discovered as long as a generation ago, or longer, and at an early date numerous attempts were made to substitute a better form of fastening. The result of it all has been that the old-fashioned hook-headed spike still remains practically the universal form of rail fastening for wooden ties, at least in this country; and, judging from the degree of satisfaction which it gives, the field for track improvements would appear to be wider in other directions. It is quite safe to say that if among track devices there be one that is remarkable for its simplicity, cheapness, durability, convenience of application and general efficiency, which has served its purpose from the first, and is still fully meeting that purpose, it is the track spike.

The principal objections urged against the use of the spike are two, namely: that it has less adhesion to the tie than some proposed forms of fastening, and in time is worked up from the rail flange by the undulations in the rail; and that in process of driving it crushes the fibers of the timber immediately surrounding it, which operates not only to destroy to some extent the adhesive qualities of the fiber, but also weakens the fiber against the lateral displacement of the spike, thus tending to permit spreading of the rails. It is worth while to analyze these objections and try to discern their real importance, for much needless anxiety and study arises from exaggerated ideas of the service required of a track spike and the conditions under which it is applied.

In the first place, the principal duty of a track spike is not adhesion to the tie, but to hold against lateral displacement—the tenacity with which the spike resists pulling from the tie is relatively of small importance. On tangents the duty required of the spikes is mainly to establish the alignment of the rails, and not so much to maintain it, for if such track be kept in fair surface there is little or no tendency for the rails to spread, and the spike is not subjected to lateral pressure of any account. Elsewhere in this volume it is pointed out that, so far as the safety of the track is concerned, under normal conditions, it would not matter if two-thirds or three-quarters of the spikes on tangents were pulled from the ties. On curves, however, the duty of the spikes in maintaining the alignment is of prime importance, for they must hold the rail against lateral displacement by side pressure from the wheels and the centrifugal force of the cars that is due to speed. Still this duty, important as it is, is imposed by only the one tendency to lateral displacement. The familiar supposition that the spikes must resist an overturning tendency in the rails is not warranted by the facts. If such was the condition imposed the spike would indeed be a poor form of fastening to prevent the overturning of the rail.

While it is true that the canting of the inside rail of curves is of frequent occurrence it is elsewhere explained that such tendency arises from the crosswise skidding of the wheel tread on the top of the rail, tending of course to overturn the rail, but being entirely too small a force to lift the inner corner of the rail flange. The resultant of the forces acting upon the rail always passes well within the rail base, and whatever tendency there is to overturn the rail is too small in comparison with the weight acting vertically downward to cause the lifting of one side of the rail flange. The result which the overturning tendency actually does accomplish is an unequal distribution of the weight on the rail base, which of course, acts more severely on the fiber under the side having the preponderance of weight, so that the compression of the fiber on that side is greater, and under certain conditions already made clear the rail gradually assumes a canting position, which is augmented with time. It should be noted, however, that it is the unequal wear or depression of the wood fiber which permits the tilting of the rail, and such action would take place just as rapidly with any other form of fastening, no matter how firmly the rail could be united with the tie. That it does take place without any apparent resistance from the spikes is therefore no indication that the spikes do not fully perform their duty. The gist of the matter is that on curves which are properly elevated the resultant of the forces on each rail passes through the center of the rail base, or very near to it, and under no conditions obtainable in ordinary practice is there an uplift on the inner side of either rail. The adhesion of the spike against an upward pull is therefore of no practical consequence, so far as concerns the point discussed. Ignorance of, or indifference to, this fact accounts for the sometimes needless practice of plugging the holes of spikes pulled and redriven in the same holes on the original line, as in renewing rails with same width of base. Some even go so far as to plug the old hole and set the spike in a new position, to obtain better adhesion, which is not required. If the alignment or gage of the rail is not to be changed by the spikes, it is better practice to redrive the spikes in the old holes without plugging, for while the adhesion is not so great as with a spike driven in a plugged hole or in undisturbed fiber, the lateral resistance to the spike is not impaired by pulling, if it is properly done.

The uplift of the rail in its undulations is resisted by the spike, and it must be admitted that to fully perform this duty the adhesion is not quite sufficient. Gradually the spike becomes lifted, even in ties of the hardest woods, especially after the tie has become somewhat deteriorated, until the head of the spike will sometimes stand ¼ in. or more clear of the rail flange. In ties sound enough to remain in the track, however, it is not usually the case that the lifting of the spikes becomes excessive. While there are those who claim that the rail should have free play vertically to the extent of its undulations from wheel loads, so as to prevent the lifting of the ties from their beds, it is doubtful if the supposed benefits from such practice can be substantiated. It must be considered that unless the rails are firmly anchored to the ties the amplitude of the undulations will be increased, which will facilitate creeping of the rails in two ways, namely, by accelerating their creeping action, and by removing an obstruction thereto, for if the spikes are kept tightly driven the ties will powerfully resist the creeping of the rails. To hold the spikes to their work it is necessary to go over the track at least once a year and drive down a large portion of them, which is, of course, a matter of some expense. It should not be understood, however, that such work becomes a pressing necessity.

It now remains to refer to some of the devices which have been contrived or introduced with a view to hold the rail firmly to the tie. The Bush interlocking bolts were devised and experimented with as early as 1882, on a number of roads, but have never come into extensive use. These bolts are shown as Fig. 490. They are inserted into holes bored in the tie at an angle of about 45 deg., and in such directions that their center lines nearly intersect in the interior of the tie, underneath the rail. The boring is done by means of a machine clamped to the rail, and the proper position and angle of the holes are fixed by the set of the bits. The lower portion of each bolt is notched out, to provide for the reception of the other bolt, so that when crossed and drawn home the bolts interlock. As it appears in the figure, to show the manner of interlocking, the right-hand bolt has not been drawn entirely home. One of the bolts must be turned after it has been driven across the other bolt, and by tightening down the nuts on the beveled clips the shoulder on each bolt pulls against a like part of the other. To remove the bolts the nut on the right-hand bolt is slackened and the bolt is driven in, to permit the withdrawal of the left-hand bolt, when the other can be freely withdrawn. The first cost of such a device is a considerable item, and it does not take a practical trackman long to discover that it is far from being a perfect track fastening, if indeed it amounts to any improvement at all over the track spike. While it is true that it ought to be capable of holding the rail very firmly to the tie, still any cutting of the rail into the tie removes the rail flange from the gripe of the clips, which cannot be made to follow up the recession of the rail without removing the clips and adzing the tie. Experience with track bolts also teaches that a nut placed upon a vibrating body, like a rail, is a difficult device to maintain in proper adjustment, so that, all things considered, a great deal of labor would be required to maintain the rail in close union with the ties with a fastening of this class.

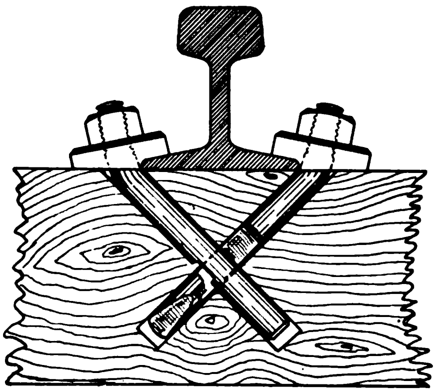


Fig. 490.

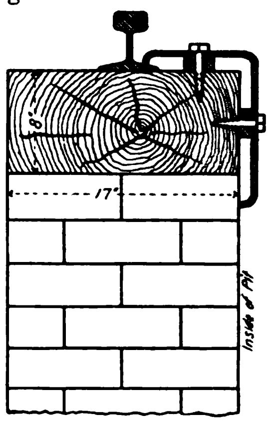


Fig. 490 A.

A simpler form of fastening which has been proposed, and tried to a limited extent on the New York Central & Hudson River R. R. and on some of the elevated railway tracks, consists in the use of clips and lag screws, on the arrangement shown in Fig. 491. Holes are bored in the tie at the proper slant and the lag screws are turned down upon the beveled clips. Each clip has a shoulder to oppose the lateral thrust of the rail flange, and the clip is slotted to permit a lateral movement of ½ in. in either direction, to provide for adjustment of the gage without resetting the screw. It is clear that the first cost and the cost of application of such devices would be greatly in excess of the cost of spikes, with no prospect of permanent results superior to those obtainable by the use of spikes. It is plain to be seen that any cutting of the rail into the tie would destroy the integrity of the fastening, and should the rail cut into the tie a depth equal to the thickness of the edge of the flange, the clip then presents no backing against the rail, and on curves the rail would cut under the clip and spread, as shown in Fig. 492, unless such cutting action of the rail was closely followed up by adzing the ties and resetting the clips. In this respect, therefore, the clip and lag screw device is inferior, in point of safety, to the spike, because the spike always maintains a backing for the rail flange. Unless used in connection with a tie plate it is difficult to see how any advantage could accrue from the use of clips and lag screws.

While it is generally considered that the track spike is not a perfect fastening it may be said without reserve that it answers the purpose better than any other device yet produced. It is the least expensive, and it may be applied and withdrawn with less labor than is required with any other form of fastening. It consists of but a single part and it cannot get loose and rattle. If on sharp curves or on curves with soft-wood ties the spike, or resort to double spiking, be not equal to the lateral thrust of the rail, the situation cannot be misleading to any competent trackman, and such devices as rail braces or tie plates may be brought to the aid of the spikes.

Considered by itself the lag screw, as a track fastening, is hardly superior to the common spike, for while it has greater adhesion in the timber, tests have shown that it meets with less resistance to lateral displacement from the wood fiber than a spike of square cross section presenting the same projectional area against the fiber. The results of some tests made in the Pittsburg testing laboratory, as published in the Railroad Gazette of Oct. 15, 1897, show that in pine wood a screw with sectional area of 0.45 sq. in. met with 67 per cent, and in oak wood 96 per cent, of the lateral resistance offered to a spike having a sectional area of 0.37 sq. in.; in cedar the lateral resistance to the screw was only 58 per cent of that offered to the spike. In European practice lag screws are very commonly used as track fastenings, in substitution for spikes, but it is quite commonly understood there that a fastening of square cross section offers more resistance to displacement of the wood fiber endwise the grain than a fastening of circular cross section. Accordingly, it is very largely the practice on European roads to use screws for gage-side fastenings and spikes for outside fastenings, as the latter afford better security against spreading of the rail.

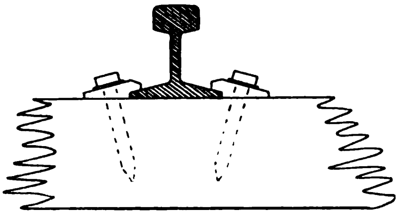


Fig. 491.

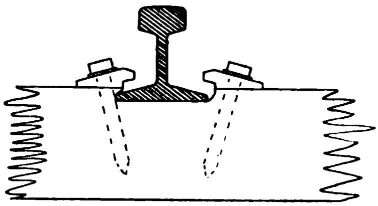


Fig. 492.

Although the adhesion of the spike in the timber has been shown to be of relatively small importance, it may nevertheless be of some interest to state briefly the results of some tests published in the journal of the Engineering Society of the University of Iowa, in September, 1891. It was found that the force required to draw spikes was somewhat variable, even with the same spikes in the same tie, due quite probably to variability in the density of the fiber in different parts of the wood. Discovery was also made of the fact, already very well known to any trackman or other person who has handled a claw bar, that while pulling a spike the adhesion in the wood decreases very rapidly after the spike has been started. In 20 tests with common track spikes newly driven 4⅜ ins. deep into a seasoned Missouri white oak tie, the average resistance to starting was 5514 lbs. The spike used for experiment was 5½ ins. long, and $^9/_{16}$ in. square, in section, with a point ⅞ in. long. In nine tests with spikes driven into the same tie in a ½-in. bored hole the average resistance to starting was found to be 4936 lbs. Compared with tests on an unseasoned white oak tie the results are quite interesting. In tests with seven spikes driven into this tie the average force required to start the spike was 4706 lbs., but when driven into a $\frac{1}{2}$-in. bored hole the average resistance to starting was 6140 lbs. The average force required to start spikes from unseasoned white cedar ties was 1140 lbs., and the average force required to start spikes driven into a $\frac{1}{2}$-in. bored hole in the same tie was 1400 lbs. The force required to start a $\frac{5}{8}$-in. lag screw set in a $\frac{1}{2}$-in. bored hole in a seasoned white oak tie to a depth of $4\frac{1}{2}$ ins., was 8037 lbs.; a $^9/_{16}$-in. lag screw set in a $^7/_{16}$-in. bored hole 3 ins. resisted starting with a force of 6480 lbs. A $\frac{5}{8}$-in. lag screw set in a $\frac{1}{2}$-in. bored hole in a yellow pine tie to a depth of 4 ins. resisted starting with a force of 3800 lbs.; and a $\frac{5}{8}$-in. screw set in a $\frac{1}{2}$-in. bored hole in a white cedar unseasoned tie to a depth of 4 ins. resisted starting with a force of 3405 lbs. While the number of tests performed and the number of pieces of timber selected for the tests were not sufficient to determine results which can be accepted as general, the results do give some idea of the relative holding powers of spikes and lag screws.

It is generally recognized that in driving the common spike having a blunt wedge-shaped point the fiber of the wood immediately surrounding it is injured to some extent, especially the fiber of soft-wood ties. While this injury to the fiber decreases somewhat the tenacity with which it holds the spike, as is shown by the above reports on tests with cedar ties, the most serious objection is found in the impairment of the fiber respecting decreased resistance to the lateral thrust of the spike, and in the greater rapidity with which such fiber will decay by rot; the fiber is also less able to support the spike in case it should be pulled and driven the second time, and the crushed fiber is in that part of the tie where the greatest pressure from the rail occurs. The difficulty may be overcome by boring holes for the spikes, somewhat smaller in diameter than the thickness of the spike. Whether or not such preparation would in all cases increase the adhesion of the spike, it is known that it would greatly improve the resistance of the spike to the lateral thrust of the rail, which is the principal duty of the spike, as already pointed out. In Europe the boring of ties for the spikes has been extensively practiced. Out of 44 European railways replying to an inquiry from the International Railway Congress in 1889, 26 reported that they were boring holes for the spikes.

There should be less difficulty in boring ties for spikes than is commonly supposed, in this country, and the extra expense should be inconsiderable. On divisions where the gage is not widened on curves the holes could be bored by machinery, in the yards, as the ties are being loaded for distribution. There need be no trouble about the joint ties, because a certain proportion of the ties—more than enough to cover the number required for the joints—could be left blank, to be bored by hand as they are placed in the track. Where tie plates are to be used it is only necessary that the holes should be staggered and gaged to correspond to the punching of the plates, which could easily be regulated by boring through templets, which would be required in any case, in order to readily locate the holes at the proper gage distance for the two rails. In boring holes where tie plates are to be used a machine, either hand or power driven, could be arranged to bore both holes for each plate simultaneously, the bits being set to correspond to the relative position of the holes in the plate. In order to embed the plates properly they might be made to follow drift pins fitting the spike holes loosely. On roads where the gage is spread on curves the boring can best be done on the ground, as the ties are placed in the track, using templets made for the particular gage desired. In this way the gage of the rails can be controlled with better accuracy than is the case with ordinary methods of widening it. Those who have experimented with spikes driven in bored holes recommend boring the hole $^1/_{16}$ in. smaller in diameter than the thickness of the spike, and not deeper than the length of the spike exclusive of the head and the portion tapered for the point. It would also probably pay to fill the holes, at the time they are bored, with some liquid wood preserver, thus rendering that part of the tie immune to water, fungi, bacteria or other agencies of decay.

171. Effects of Bad Counterbalancing.—It is generally understood that the wear and tear to track caused by locomotives is in much greater proportion than the ratio of their weight to that of the trains they pull. While the inequality of detrimental effects is not due entirely to the relative magnitude of the locomotive wheel loads, yet extent of loading is one of the important considerations in the case. To start with, then, it will be well enough to look at the wheel loads or static wheel pressures of some of the heaviest locomotives and cars in service. One-hundred-ton locomotives are no longer phenomenal. Road engines weighing 115 to 125 tons are numerous; and there are some (A., T. & S. F. Ry.) weighing 143.6 tons. Engines exceeding 100 tons in weight are in service on a good many roads. Average loads of 12 to 13 tons per driver are quite common, and they have even reached 14 tons (Bessemer & Lake Erie R. R. consolidation engines). The average driving-wheel loads of a large number of locomotives built during the years 1900 to 1902, inclusive, for 30 representative railroads, were as follows: for 4-driver locomotives, 11.1 tons per driver; for 6-driver locomotives, 10.7 tons per driver; 8-driver locomotives, 10.4 tons per driver. The weight of some freight cars of 110,000 lbs. capacity, loaded, is 76 or 77 tons, making a wheel load of about 9½ tons. The wheel load of heavy coaches, sleeping and dining cars is about 4½ tons. The average wheel load of freight cars, is, however, much smaller than the maximum, because a large percentage of the freight cars in transit are hauled empty or loaded under the full capacity. In consideration of this fact it cannot be far from general practice to put the average car wheel load at 5 tons and the average driving-wheel load at 10 tons, observing that driver loads remain constantly the same. Thus, to begin with, the average static loading of locomotive drivers must operate with much greater severity on track surface than the average static car wheel load. The average static driver load is, however, no safe measure of the actual pressure of that wheel on the rail at speed, for reasons now to be considered.

While a locomotive is using steam the distribution of its weight on the wheels is constantly undergoing change. When the engine is working forward the oblique push and pull of the main rod acts downward on the crank pin and upward against the guide bars, on both the up and down strokes, increasing the rail pressure of the main wheel and tending to lift the forward end of the frame from the truck and transfer some part of its load to the drivers; and this changing or shifting tendency is remitted at the end of each stroke of the piston. When the engine is working backward the same action of the main rods tends to pull the front of the engine more heavily down upon the front truck and reduce the rail pressure of the main wheels. Thus from front to rear of engine, while working steam, there are rapidly acting forces which operate to throw the loading of the front truck and drivers out of the normal distribution or balance, and so administer abnormal pressures upon the rails. While the actual fluctuation of loading on the drivers and truck wheels due to this behavior of the engine has not been definitely determined in any case, the matter has been studied to some extent in connection with the subject of rail stresses, and the distribution of the loading is considered to be quite variable.

There is, however, another source of impairment to the track, originating from the action of the moving parts of a locomotive, concerning the relative magnitude of which but little doubt can exist, for in extreme cases, under conditions to be discussed, great and positive injury is done to the track—and that is the action of the locomotive counterbalance. The necessity for balancing locomotive drivers to counteract the centrifugal forces produced by the rotation of the crank pins and side rods is plain. So far as these revolving parts are concerned there is no difficulty in putting the drivers in perfect balance, except for a certain "nosing" effect due to the counterbalance in the wheel and the revolving parts not being in the same plane, which has some tendency to turn the engine sidewise. In order to overcome a certain shaking effect on the engine frame due to the movement of the reciprocating parts, known as "plunging," it is necessary to place additional balance metal in the wheels, or an amount in excess of that required for the revolving parts. The centrifugal force of this excess balance is counteracted by the reciprocating parts only in the horizontal direction, thus leaving the wheels out of balance vertically. Such a condition exists in practically all well built locomotives. The effect of this overbalancing is a tendency in the wheel to revolve not about its geometrical center (the center of the axle), but about its center of gravity, or, providing the centrifugal force is sufficient to overcome the inertia of the wheel, there is set up what might be called a wabbling motion in the wheel. Such wabbling motion actually will take place with any ordinary locomotive driver at sufficient speed, causing it to lift from the rail at one point in each revolution and exert a very great blow or pressure on the rail at another point of the same revolution. The problem at hand in counterbalancing any locomotive is therefore to fully balance the wheels for all revolving parts and use as little additional balance for the reciprocating parts as will serve to overcome disagreeable motions of the engine and relieve the frame and working parts of undue stresses when running at the maximum speed for the service in which the locomotive is intended. In other words, it is impossible to completely balance all the moving parts of a locomotive of ordinary design. If only the revolving parts are balanced the engine will be out of balance horizontally, and if the reciprocating parts are fully balanced the engine will be badly out of balance vertically. Again, the revolving parts at any certain speed have a constant velocity, whereas the velocity of the reciprocating parts is necessarily variable in every stroke. Out of such considerations it is necessary to compromise. The effect of the overbalance vertically is stated above. The effect of the unbalanced reciprocating weight is a tendency at one quarter of the revolution to push one side of the engine forward and at the next quarter the opposite side; and at the third and fourth quarters the racking stresses are respectively backwards.

In actual practice only one half to two thirds of the weight of the reciprocating parts is balanced in the driving wheels. The parts considered as having a reciprocating motion are the piston, piston rod, crosshead and the front end of the main rod, the rear end of the main rod being considered to have a revolving motion. A rule favorably reported upon at the annual convention of the American Railway Master Mechanics' Association, in 1897, and which seems to have been followed quite extensively in general practice, requires the balancing of the drivers on each side for the weight of the reciprocating parts on that side less one four-hundredth of the total weight of the engine. This portion of the counterbalance is to be distributed equally among all the driving wheels on one side, adding the weight of the revolving parts for each wheel separately. This rule takes into account the weight of the engine and assumes that a heavy engine can stand more unbalanced reciprocating weight without detriment to its smoothness of working than a lighter one. Undoubtedly the design of the engine has also some influence on the matter of counterbalancing, as it is generally supposed that an engine with a given proportion of weight on the front truck will stand more unbalanced weight in the reciprocating parts without disagreeable motion or injury to the engine than one with less weight on the front truck. The length of the driving wheel base very likely has an important influence, also; the shorter the base the more readily would the machine be expected to plunge. Thus in some cases it has been reported that with eight-wheel engines in fast passenger service a larger proportion of the total weight of the engine than one four-hundredth has been taken as the allowable unbalanced weight of reciprocating parts on each side, and that an increase in the unbalanced weight can be made in proportion to the length of the engine. At a speed of the engine in miles per hour equal to the diameter of the drivers in inches the increase and decrease of the wheel pressure on the rail in each revolution, due to the overbalancing of the wheel for the reciprocating parts, has been found by calculation to be 38.4 times the weight of the excess balance. In order therefore that the wheel shall not leave the rail at the speed indicated, the portion of the counterbalance allowed for the reciprocating parts must not exceed the static pressure of the wheel on the rail divided by 38.4; and to insure safety such increase or decrease of pressure should be kept within an amount equal to the static pressure of the wheel on the rail.

It does seem like expecting a good deal of track to take for granted that it will stand any wheel pressure brought to bear upon it just so long as the wheel does not lift and drop upon the rail at each revolution, for very heavy rail pressures (approximating to double the static pressure of the wheel) may obtain before actual lifting takes place. It seems as though the matter should receive very careful attention at the hands of both the mechanical and track departments, for the increase of rail pressure from overbalanced wheels, even at moderate speed, must exert a considerable effect upon track surface. The amount of overbalance should therefore be reduced to the lowest possible limits consistent with satisfactory running of the engine and allowable stresses in the parts.

It has been stated that the pull and thrust of the main rod when the engine is working forward increases the rail pressure of the main wheel. This increase of pressure acts with the increase of pressure due to the overbalance of the wheel, and against the lifting force due to such overbalance; which is to say that while the counterbalance is passing below the center of the wheel the centrifugal force of the overbalance acting downward at that time is increased by the downward component of the pull of the main rod, while during the passage of the counterbalance above the center of the wheel the centrifugal force acting vertically as though to lift the wheel is counteracted by the amount of the downward component from the thrust of the main rod. Thus it happens that, so far as the main wheel is concerned, while the engine is working forward, the decrease of wheel pressure on the rail due to the centrifugal force of the overbalance must exceed the static pressure of that wheel by the downward component of the main rod pull before the wheel can lift; while as regards the increase of rail pressure at the downward throw of the counterbalance, the maximum pressure which takes place in the same revolution when the decrease of pressure is just sufficient to lift the wheel from the rail, cannot be less than twice the static pressure of the wheel plus the vertical component from the thrust of the main rod. When the engine is working backward the reverse obtains; that is, the vertical component of stress from the main rod is downward against the guide bars and upward against the crank pin, on both the up and down strokes, and such lifting force on the crank pin operates to diminish the increase of pressure due to the centrifugal force of the overbalance, and to augment the decrease of pressure due to such force; so that the action of the overbalance can pound the track with less severity while passing below the center of the wheel, but the wheel is able to lift from the track at a less speed than when the engine is running forward. Such considerations would make it appear that in the distribution of the counterbalance among the drivers on each side of the engine the main wheel should receive less than its proportionate amount of that part of the balance inserted for the reciprocating parts.

Fig. 493.—Rails Damaged by High-Speed Running, Mo. Pac. Ry.

This brief exposition of some of the forces exerted upon the track, as developed from locomotive operation, must show that all of the shocks or rail pressures which actually take place are very complicated of determination, if not practically indeterminate, for evidently there are many kinds of pressures acting simultaneously. Instances of damage to track by the action of excess counterbalance at high speed have been of more or less frequent occurrence and are sure to take place where locomotives exceed the speed for which they are balanced. Some details regarding damage of this kind will serve to indicate the magnitude of the forces acting. Figures 493 and 494 are views reproduced from photographs of track damaged at one time on the Missouri Pacific Ry., near Jefferson City, Mo. On this occasion the rails on three miles and 2780 ft. of track were badly kinked and had to be removed from the track. The rails on 2190 ft. of track were of 75-lb. section, and on three miles and 590 ft. of track they were of 63-lb. section. The engine was of the consolidation type with drivers (eight) 44 ins. in diameter., the weight on the drivers being 45 tons. At the time the damage occurred the engine was not pulling a train, and is supposed to have been running between 45 and 50 miles per hour. The rails were sharply kinked at intervals corresponding to the driving wheel circumference, the kink in all cases being vertically downward and inward toward the center of the track, as indicated by the loose rail in Fig. 494, which was removed from the inside of the curve and placed in the middle of the track for the purpose of photographing. The two views show that the damage was inflicted alike upon curves and tangents, and the view of the straight line forcibly reminds one that the stresses which must have acted upon the bridge shown were undoubtedly in excess of anything calculated upon in the design of its members. It is somewhat interesting to notice that in all cases of track damaged in this manner the lateral bending of the rail is inward, or toward the middle of the track. This phenomenon is probably explainable on the fact that the pressure from the wheels is applied inside the middle line of the rail head, thereby causing it to swerve inward as the rail is kinked downward.

Similar damage has been observed to take place in hauling "dead" locomotives with the side rods taken down, or when running engines with only one side connected, even at a moderate rate of speed; which is easily explained by the fact that the removal of the rods leaves the wheels very heavily overbalanced, the entire counterbalance then being excessive where the side rods are removed. By way of illustration, a six-wheel engine of the Wabash R. R. with side rods disconnected, in being hauled to the shop in a freight train, between Huntington and Andrews, Ind., pounded the track so heavily that 772 rails had to be removed, 10 of them being broken. The engine which did the damage had 56-in. drivers, and the train was running at a speed of 40 to 45 m. p. h. The rails were "kinked" or surface-bent at points a uniform distance of about 15 ft. apart, and the depressions were nearly all from the outside of the rail head, as though the engine had delivered a blow diagonally downward and inward to the track. The weight of the rail was 63 lbs. per yd., and out of the 772 damaged rails 600 were on one side of the track, none on this side escaping punishment; on the other side the indentations were scattered, and not generally opposite those on the other side. Some roads have a rule that the maximum speed of freight trains hauling "dead" or disconnected engines shall not exceed 20 m. p. h. It is required on a number of roads that side rods must be in position on locomotives while in transit, the rule having special reference to new engines hauled in the freight trains.

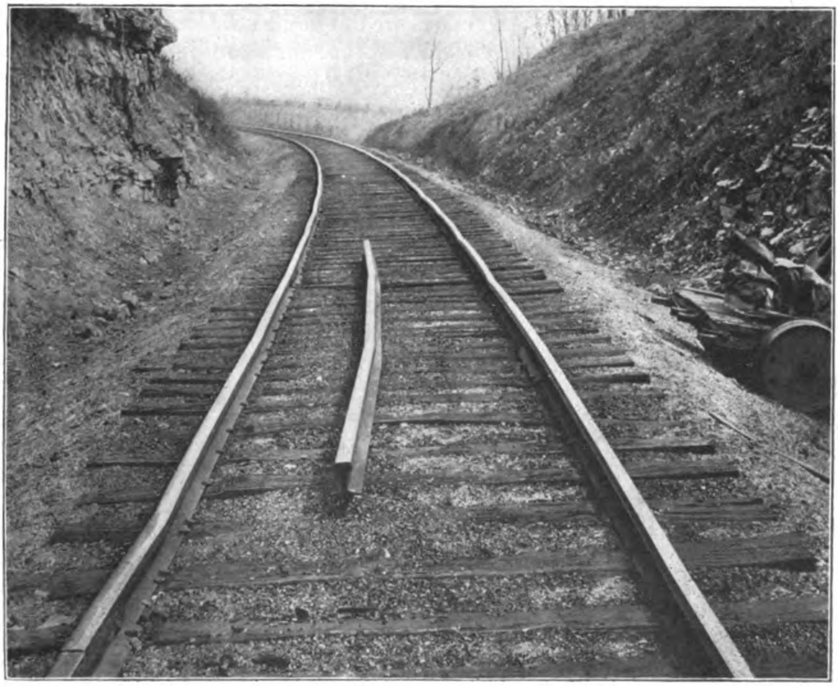


Fig. 494.—Rails Damaged by High Speed Running, Mo. Pac. Ry.

It is also to be expected that an improper distribution of the counterbalance among the drivers will lead to excessive pressure from the driver most heavily overbalanced under the conditions imposed. As a matter of fact it appears that in nearly all cases where injury has been done the track from counterbalance effects, the damage has come from only one wheel on each side of the engine.

That a wheel carrying excessive counterbalance will actually lift from its support at high speed was proved by Professor W. F. M. Goss in some experiments conducted in the mechanical laboratory at Purdue University. Lafayette, Ind., in 1893. The details of these experiments, which are exceedingly interesting from the standpoint of the maintenance of way engineer, are stated in § 204, Supplementary Notes.

In a preceding paragraph it is stated to be impossible to completely balance all the moving parts of a locomotive of "ordinary design." It is practicable to so design a locomotive that the reciprocating parts will be in balance, and for many years a few mechanical engineers have urged such construction. With the reciprocating parts in balance no overbalance of the driving wheels is necessary. In that case the drivers are counterbalanced for the revolving parts and all of the working parts are then in balance. The famous 20,000th locomotive of the Baldwin Locomotive Works, completed in February, 1902, and prominently known in connection with the seventieth anniversary of the operation of that institution, was built in this way. This was a 10-wheel passenger engine for the Plant System (No. 119). It is a four-cylinder compound machine, the two low-pressure cylinders being outside the frame, in the usual place, and the two high-pressure cylinders between the frames or between the two low-pressure cylinders, being cast with the saddle, so that the axes of the four cylinders are parallel and in the same horizontal plane. The pistons of the outside cylinders are connected with crank pins on the main wheels (which in this case are the front drivers), in the ordinary way, and those of the inside or high-pressure cylinders with cranks in the main axle. The crank in the axle and the crank pin on the driver for the corresponding high and low-pressure cylinders are set 180 deg. apart, so that the two sets of pistons, piston rods and cross heads on each side of the locomotive simultaneously move in opposite directions. As the weights of these reciprocating parts for the high and low-pressure cylinders are made nearly the same the working parts are almost perfectly balanced. As each driving wheel is counterbalanced for its own rotating weight and for no reciprocating parts there is therefore no unbalanced rotating weight in the wheels, and no "hammerblow" effect. In 1903 the Atchison, Topeka & Santa Fe Ry. had in service four balanced compound Atlantic type passenger locomotives built with a crank main axle and designed in this way; but it is questionable whether such features of design will come into general service in this country, for the crank axle has always been objectionable from the American point of view.

172. Longer Rails.—Just why 30 ft. came to be so universally adopted as the standard length for track rails in this country is not a matter of record, but it may readily be surmised that convenience of transportation had a good deal to do with it. For many years the length of ordinary flat cars was such that a rail longer than 30 ft. could not be conveniently handled thereon in shipment; and it is also probable that in the early rolling mills a sufficient quantity of metal for making a rail longer than 30 ft. could not be handled in a single ingot. However this may have been such difficulties no longer survive, but 30 ft. remains the general standard length of rail. The one great advantage to be obtained in the use of rails longer than 30 ft. is a decrease in the number of joints. In order to eliminate joints or the effects of the same, three lines of improvement have been proposed and experimented with to some extent, namely: (1) to rivet the rails together at the joints, continuously, without allowance for expansion; (2) to firmly unite the rails at the joints, in stretches several hundred feet in length, without allowance for expansion, by providing slip joints or devices to receive the expansion at the ends of the sections; and (3) to increase the length of the rail considerably, say 50 to 100 per cent.

Although it is commonly the practice in street railway construction to butt the rails closely end to end, with no allowance for expansion, no well informed trackman would be guilty of suggesting such construction for the ordinary type of track on steam roads. In street car tracks all except the top of the rail is covered by the earth or by the pavement, so that on a hot day the rail readily loses its heat by conduction. It is further to be considered that the street railway track is firmly held by the earth or pavement that is closely packed about it, so much so that it is quite impossible for the track to be moved out of line by rail expansion during a hot day; and the rail is compelled to undergo the stresses set up by the expansion of the metal, without lengthwise extension. On street railway track where the rail is not closely protected by earth or pavement one will observe that, unless there is allowance for expansion, the rail, on very hot days, is thrown into slight kinks, showing that the metal is under tremendous stress. Theoretically this stress is about 200 lbs. per sectional square inch of metal for each Fahrenheit degree increase of temperature. As the ties are solidly embedded, however, they cannot be moved out of line and the spikes are able to hold the rail to a safe general alignment. As such conditions do not obtain to any considerable extent on steam roads, however, the practice of the street railways is no criterion for general practice on steam roads. Experienced trackmen well understand the dangerous tendency of track on steam roads, especially on curves, where sufficient allowance for expansion (not to speak of no allowance at all) for the extreme temperature of hot weather is not provided for.

In this connection mention may be made of the famous "Noonan" experiment, on the Lynchburg & Durham Ry. (now part of the Norfolk & Western Ry.) in 1889. In June of that year three miles of track near Glady's Station, Va., was laid according to plans devised and patented by a section foreman named Philip Noonan. In laying this track the ends of the rails (56 lbs. per yd.) were brought into contact and firmly united in a continuous stretch over the whole section of three miles. The joint fastening consisted of heavy fish plates ¾ in. thick, drilled with round holes to correspond to the bolt holes in the rails, and secured by four 1-in. rivets, driven hot, with the aid of drift pins to tightly close the joints. This splice proved to be all that was expected of it, for it was found that the joint would not open in the slightest amount, and in this respect the rail was practically continuous. The spikes were not driven home, the heads remaining ⅜ in. clear of the flange, to permit undulations in the rail without disturbing the spikes or the ties. At each end of the 3-mile section the rails were turned out and switch points were laid to take care of the expansion. The track was ballasted with dirt and the ties were covered with earth, consisting of red clay and loam, extending to the under side of the rail head, between the rails, and to the top of rail on the outside of the track. To prevent dust, the filling material on part of this track was turfed over, and grass seed was sown over the remainder (unusual practice, indeed). While the riveting was in progress, and before the track had been surfaced, lined and buried, some trouble was had from expansion of the rails, but not afterward.

It was expected that this track would remain "self-surfacing," and after a test of 17 months the managing official, Mr. R. T. Gleaves, declared before the Engineers' Club of Philadelphia that there had not been the slightest buckling of the rails (the three-mile section included some curved track) and that the track had not been surfaced or lined since it was first put in running condition. Engines weighing 104,000 lbs. passed over the track at a speed of 50 miles per hour. Owing to the fact that the track was laid on newly-made roadbed it settled out of surface, to some extent, but on the whole the experiment was reported to have been very satisfactory. During the same period the expense for labor in keeping up an adjoining three-mile section was $1890. In due course it was ascertained that the ties decayed prematurely, and no report seems to have been made public of the expense of digging out and surfacing the track when such repairs eventually became necessary. Finally the experiment dropped out of sight, and, so far as has been generally known, has not been repeated. It is hardly necessary to add that such construction is not particularly enticing to trackmen; and it may be safely said that the expense of filling the track and the vast amount of labor required to remove the material when surface repairs and tie renewals become necessary present a forbidding aspect.

An experiment of the second kind above referred to was begun on the main line of the Michigan Central R. R., in the suburbs of Detroit, Mich., in November, 1894. At this point four consecutive sections of experimental track, each 500 ft. in length, were laid with 80-lb. rails butted end to end and firmly spliced together, without allowance for expansion. The rails were spliced with six-bolt 44-in. angle bars, in the ordinary manner, with four additional 1-in. machine-made bolts in the middle of the first, second, fourth and fifth spaces between the ordinary bolts. Harvey "grip" bolts were used, well set up, and the splices were made to hold the rails so firmly that no opening could take place at the joints. At each end of the 500-ft. stretch the rails were coupled by a slip joint of special design, with an outside reinforcement to carry the wheels. This slip joint was designed to provide for 4½ ins. of expansion. At the middle of the 500-ft. section two ties were held to concrete anchorage by U-shaped pieces of rail embedded in the concrete mass underneath the track, and the rails were held to the anchored ties by special splices and lag screws. Whatever expansion could take place, therefore, would have to be exerted from the middle of the section toward the slip joints at the two ends. The actual expansion at each slip joint—that is, between the middle points of each two adjoining 500-ft. sections—between the two extremes of temperature, was found to be about 3¼ ins., so that the expansion allowance was ample, and there was no tendency to buckling of the rails. After the experiment had been in progress eight years the track had remained in good surface without any tamping, except what was done soon after the rails were laid, to put the track in first-class condition. The results were so satisfactory that in 1901 a further experiment on a much larger scale was begun on substantially the same lines. At a point on the Bay City division of the road, a few miles out of Detroit, a mile of track was laid with 60-ft. rails tightly spliced together in 500-ft sections, without allowance for expansion. Slip joints are used between the long sections, as at Detroit, but the method of anchoring to prevent creeping track is somewhat different. The rail at the middle of each 500-ft. section is anchored to a piece of old rail about 15 ft. long set vertically in a mass of concrete deposited in a hole excavated into the roadbed. The top of this anchor rail rests against, and projects slightly above, the flange of the track rail, fitting into a notch in the horizontal leg of a splice bar. These experiments were planned by the late Chief Engineer A. Torrey.

Rails 33 ft. long are extensively used on a good many roads, and an increase in the standard length of rail to 33 ft. has been recommended by both the Roadmasters' and Maintenance of Way Association and the American Railway Engineering and Maintenance of Way Association. Rails longer than 33 ft.—mostly 45-ft. and 60-ft. rails—have been tried on but comparatively few roads. The results have been of a varying character, and the experimental stage in the use of such rails cannot yet be considered to have been passed. The objectionable features which have been found in the use of rails longer than 33 ft. may be summarized as follows: (1) surface kinks in the rails due to improper straightening at the mills; (2) excessive pounding at the joints, due to the increased allowance for expansion; (3) the rails are not as readily and conveniently transported and as cheaply handled as are rails of standard length. On the first point some mill men claim that, owing to the heavier weight to be handled, and other difficulties, it is impracticable to straighten 60-ft. rails as well as 30 or 33-ft. rails, and that the excessive gagging required by the long rail is liable to injure it. It is claimed that the best product is to be expected in rails not exceeding a length of 33 ft. Those who dispute these claims contend that some mills do straighten 60-ft. rails properly; that the matter of straightening is only a question of mechanical skill; and that rails as long as 60 ft. can be straightened as well as rails 30 ft. long, but necessarily at greater cost. Concerning the question of excessive pounding at the joints of rails longer than 33 ft. there is difference of opinion, as is also the case with the matter of handling and transporting the rails.

The Lehigh Valley R. R. began using 45-ft. rails with miter-cut or skew ends about 1890, and for seven or eight years they were the standard of that road. They were finally abandoned, however, as the standard, and the use of 30-ft. rails was again taken up. Mr. A. Morrison, at one time roadmaster with the Lehigh Valley R. R., has stated that in his experience with 45-ft. rails he found it was cheaper to handle and lay them than 30-ft. rails; that it was cheaper to maintain the track with 45-ft. rails than with 30-ft. rails, and that it was also easier to line out kinks in the 45-ft. rails. Previous to the time when 45-ft. rails had been adopted it was the practice to curve 30-ft. rails for laying on sharp curves, but with 45-ft. rails it was found unnecessary to do this, even for curves as sharp as 10 deg. The 45-ft. rails were unloaded from the rear end of the work train by means of a 15-ft. chain, hook and clevis, the rail being permitted to drop into the middle of the track as the train was pulled ahead, without injury to the rail. The rails were then thrown outside the track by two men with bars. His only unfavorable criticism of 45-ft. rails was the wider space necessary for expansion at the joints, for which reason the joints could not be maintained in as good condition as with 30-ft. rails. Experience with the miter-cut ends on this road was also unsatisfactory, one of the difficulties being that the long corner of the head overhanging the end of the web portion would break off. The battering and flow of metal at the ends of miter-cut rails is reported to have been as great as with ends squarely cut. The Buffalo, Rochester & Pittsburg Ry. began using 45-ft. rails to a limited extent about 1895, and after an experience of six years these rails, with both miter and square ends, were reported to be giving satisfactory service. The only defect which has been noticed with 45-ft.

rails on this road was the imperfect straightening found when the rails came from the mills. It is thought that better track has been maintained at the same expense as that required for track with 30-ft. rails. No trouble has been experienced with abnormal openings from creeping due to change of temperature, and there has been no battered joints.

In 1891 the Pennsylvania R. R. began experimenting with 60-ft. rails of 85-lb. section, and after 10 years this length was "condemned" as unsatisfactory. On straight track, where there were no grades, a measurable degree of satisfaction was obtained, but on grades, where creeping was troublesome, these rails gave poor satisfaction, even where two and three anti-creeping fastenings had been applied to each rail, besides slot-spiking at the joints. The chief difficulty was that the creeping of the rails caused them to "bunch," and in cold weather openings as wide as $\frac{5}{8}$ to $\frac{7}{8}$ in. were commonly found. Under these conditions the receiving rails at the joints were badly punished. Between the years 1892 and 1896 the Norfolk & Western Ry. laid 25 miles of track with 60-ft., 85-lb. rails with miter ends, and 60 miles with the ends cut square. These rails were laid on the heaviest grades and on sections of the road over which the heaviest traffic passed, and gave good satisfaction, the maintenance expenses being noticeably reduced. On 6-deg reverse curves 60-ft. 85-lb. rails carried 91 million tons in $7\frac{1}{2}$ years, when they had to be removed on account of flange wear. The grades were 70 ft. to the mile and trains were handled with pushers. The track was ballasted with furnace slag and the rails were connected with Churchill joint splices 23 ins. long, extending $3\frac{1}{4}$ ins. below base of rail. It is reported that no trouble arose from battering of the rail ends by reason of the joint space allowed for expansion. The Chesapeake & Ohio R. R., has experimented with square-cut 60-ft. rails, weighing 75 lbs. per yard, and after an experience of some years good satisfaction was reported. A number of other roads have tried both 45-ft. and 60-ft. rails. On the Philadelphia & Reading Ry. 45-ft. rails have been found advantageous.

The expansion allowance required for 60-ft. rails is double that for 30-ft. rails, under the same conditions, and for 45-ft. rails it is in the same proportion. The spacing for 60-ft. rails adopted by the engineering department of the Baltimore & Ohio R. R. progresses uniformly from a tight joint at 125 deg. and above, to an opening of $\frac{5}{8}$ in. at zero temperature. This allowance, it will be seen, is $\frac{1}{8}$ in. for each 25 deg. below the maximum temperature, or double the opening usually made for rails of 30-ft. length, which is $^1/_{16}$ in. for each 25 deg. difference of temperature. In long tunnels there is usually but little change in the temperature, and but little or no open space need be left at the joints for expansion. It would therefore seem that in such places 60-ft. rails should be well adapted, without any question. For 60-ft. rails it has been customary with the mill people to exact an extra charge, $2 per ton being the extra price paid in some cases. With some roads this extra charge has been the reason for discontinuing the use of "longer" rails.

In the transportation of long rails it is the practice with some companies to lay them over two flat or gondola cars, using bolsters, and in other cases rails as long as 60 ft. are loaded on alternate cars, the ends projecting equally past the loaded car, over the idle cars adjacent. In every case where the same rail rests upon two cars it is recommended that bolsters be used, in order to prevent injury to the rails by the side and vertical motions of the cars. The Lake Terminal R. R., operated by the Lorain Steel Co., has 100 long cars for the transportation of 60 and 62-ft. rails, built on plans prepared by Mr. F. H. Stark, master car builder of the Cleveland, Lorain & Wheeling Ry. The length of these cars over the end sills is 66 ft. 4 ins., the width 8 ft. 11 ins. and the capacity 80,000 lbs. The car is stiffened with eight under truss rods of 1¼ ins. diameter, passing through the end sills, and four other under truss rods of the same diameter passing up through stirrups straddling the side plank, and thence through the end plank. Passing through the stirrups straddling the side planks in the center of the car are four counter truss rods 1⅛ ins. in diam. passing down through a wrought iron plate held across the end of a block bolted beneath the side sills and abutting against the end of the needle beam. The cars have a permanent 6x8-in. floor bolster over each truck, and the cars are trussed to a camber of 4 ins., so that the long rails rest upon the bolsters nearly level.

In unloading long rails from cars by hand, a larger force is required than is the case when handling 30-ft. rails, but the ordinary work-train crew is easily able to do the work. Quite frequently 60-ft. rails have been unloaded by hooking a 30-ft. rope to the end of the rail and anchoring it to the track, the rail then being drawn off the car as the train is pulled ahead. The end of the rail is then lowered from the car to the track by a gang of men, as the car is pulled from under it, or in some cases it is allowed to drop freely on the ties, the long sag being so deep that the rail drops without injury. Two men with bars then throw the rail out of the track. In renewing rails the number of tongsmen required to handle 60-ft. rails is double the number for 30-ft. rails, but only half the number of bolters is required. It has been stated that, on the whole, there is a saving of fully 15 per cent in handling and laying 60-ft. rails as compared with the expense of handling and laying 30-ft. rails in the same length of track. The cost of unloading and laying 60-ft. rails on the Norfolk & Western Ry. is reported to have been 20 per cent less than the cost of handling 30-ft. rails in like manner, for an equal length of track.

In Germany the old standard length for rails was 29½ ft., and the experience from increasing this length seems to have resulted more satisfactorily than has been the case in this country. An increase of 33⅓ per cent or to 39 ft. 4 ins., seems to have met with general approval. On some roads the standard length has been increased to 59 ft.

173. Compound Rails.—The effort to produce a continuous rail has led to numerous proposed designs on the principle of dividing the rail into longitudinal parts to be bolted or riveted together so as to break joints. An old idea, and one which is said to have succeeded to actual trial, was to roll the rail in two parts separable vertically through the middle plane of the web and bolted or riveted together so as to break joints, without splices. If it were not for the necessity of allowing space for expansion such a design might have stood some show of success, years ago, because a joint extending entirely across the rail could have been avoided; but even then, without splice bars, the rail at joints between contiguous sections would have been weakened to one-half the strength or stiffness at intermediate portions. The necessity for expansion allowance, however, forbids a rigid union of the parts, so that it would not have been possible to get them to act together, the result of which would have been a shaky affair. At the present time such a design obtains no right to consideration, even if it was practicable to rivet the two halves rigidly together, because if allowance for expansion could be dropped out of consideration present methods of cast-welding or electrically welding rails could be applied with greater advantage and economy.

With the two-fold object of making the rail continuous and to provide a part which need not be scrapped when the head becomes worn out, it has been proposed to divide the rail into top and bottom parts. A familiar design which numerous inventors have worked upon consists of a rail head of ordinary form (*A*, Fig. 495) with a depending tongue or web portion, fitting into a grooved base; or, vice versa, a rail head with a depending grooved portion, into which is fitted a base with an upwardly projecting tongue portion. Some have proposed to make the base solid or in one part, like the Bargion rails, laid experimentally by the Southern Pacific Co., at Oakland, Cal., in 1890; while others, to facilitate rolling or to provide increased bearing surface for the head, have proposed to divide the base into two parts (*B* and *C*, Fig. 495). The top and base portions are then to be riveted or bolted together to break joints. In this case, also, the necessity for expansion allowance gives rise to a fatal defect in the design, for unless the parts could be riveted to make absolutely rigid connection, whether the base portion be solid or in two parts, the different parts of the rail could not be made to act together, and there would be simply the strength and stiffness due to the head and base portions acting independently. To show that such a design is extremely faulty from other considerations it is only necessary to point out that each part has but one flanged portion and each part is considerably shallower than the depth of the entire rail, thus greatly lacking in stiffness. Moreover, the holes provided for riveting or

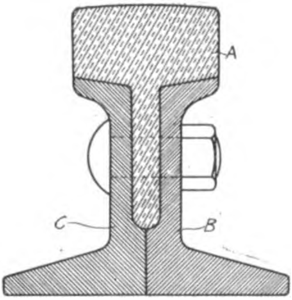
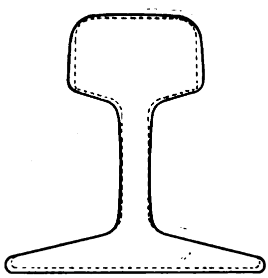


Fig. 495.



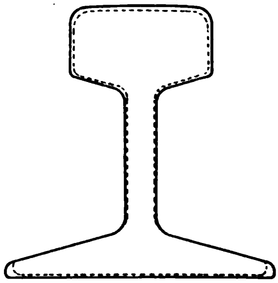


Fig. 496.—Rerolled Rails—Fig. 497.

bolting the parts together, being outside the neutral axis of the section, in each case, weaken those parts unduly and increase the liability to fracture or break at the holes. In order to make a rail of this design as stiff and reliable as the rail of simple section in ordinary use would require a base portion so enormously heavy that interest on the cost of extra metal would more than eat up any saving which could be effected in cost of maintaining track surface or in the prolonged service of a portion of the rail exempt from the scrap pile.

The Bargion rail, above referred to, had a solid grooved base of soft, tough steel, of a quality intended to withstand stress and shocks, and a head with a depending tongue, made of hard corbonized steel, for wear. The base or lower part was first rolled open, in star shape, until the last pass, when the double web was closed in to the proper shape. From the fact that it was rolled in one piece there were no flanges on the top edges of the double web, as in Fig. 495. The rail weighed 138 lbs. per yd., of which the base weighed 75 lbs. and the head portion 63 lbs. Head and base were fastened together with rivets. The rail was successfully laid on a $7\frac{1}{2}$-deg. curve. It failed by cracking and breaking through the rivet holes. The design of compound rail proposed by Mr. Walter Katte, formerly chief engineer of the New York Central & Hudson River R. R., was similar to Fig. 495, the difference consisting in an enlargement of the tongue portion of the head on line with the bolts, the inside faces of the double web being grooved out to correspond. The Haarmann compound rail is described in connection with Metal Ties, §203 Suppl. Notes.

174. Rerolling Rails.—It is familiar to the experience of many railway men that rails of inferior quality are rendered unserviceable for main track use more from flowing and roughening of the head than from serious loss of metal. In any case it is not practicable to use up more than 15 or 20 per cent of the metal in a rail, in wear, by the traffic, and it is seldom that the metal worn away in main-track service amounts to as much as 12 per cent of the weight of the rail. The limit of wear in main-track service is ¼ to ⅜ in. in depth of head. The rest goes to the scrap pile and, taking one year with another, will sell for about 40 per cent of the price per ton of new rail, after deducting freight charges. Thus, on a basis of 12 per cent wear, about 53 per cent of the price paid for the rail is lost by depreciation, the oxidation of rails usually being but very little. Some years ago it occurred to Mr. E. W. McKenna, assistant general superintendent of the Chicago, Milwaukee & St. Paul Ry., that the unworn portion of rails commonly taken up in renewals contains sufficient metal for a rail nearly as large in section as that of the original rail; and that if a cheap process of rerolling the worn rail could be devised, a new rail of but slight reduction in section could be produced at low cost, which would work an important economy in the expense of rail renewals. After some study of the matter machinery was fitted up in the North Chicago rail mill of the Illinois Steel Co., and in the fall of 1895 trial orders for rerolled rails were executed for the Chicago, Milwaukee & St. Paul; Atchison, Topeka & Santa Fe; Chicago, Burlington & Quincy; Michigan Central; and Baltimore & Ohio roads.

The experience with these rails showed that added serviceability to the rails could be cheaply gained at the cost of rerolling, and in 1897 a new mill was built at Joliet, Ill., specially equipped for the work. In this mill there are two furnaces for heating rails, so arranged that the rails can be charged in at one end of the furnace and drawn out at the other. Each furnace has a capacity for 21 rails, and the time required to heat the rails to the desired temperature—1700 deg. F.—is about 35 minutes. At this temperature the metal is a bright cherry red, which is below the decarburization point. The rails are withdrawn from the furnace one at a time, and as soon as seven have been withdrawn a new charge of seven rails is run in at the other end of the furnace. Each rail after being taken from the furnace receives three passes in the rolls, or one pass in each of three sets of two-high rolls in tandem. The first set, which operates directly in front of the furnace, and draws the rail out of the furnace, is known as the "upsetting" rolls, and through these the rail is passed workwise. The purpose of these rolls is to compress the rail vertically, so as to force the head and flange, and consequently the fishing surfaces, nearer together and reduce all the rails to a uniform hight. The rail then goes to the second set, known as the "roughing" or "forming" rolls, which have three grooves each designed to receive definite forms of worn rail. From the third and last set of rolls, known as the "finishing" rolls, the rail emerges at a temperature of about 1400 deg., whence it is taken to the hot saws, hot beds, straightening and drilling machines, in the usual way. The average time of the rolling process, from furnace to hot saws, is only 29 seconds. The capacity of this mill is 400 tons of rails rerolled in 24 hours. In Kansas City, Mo., there is another mill of equal capacity and similarly operated, built in 1898. At Tremley Point, N. J., there is a mill of 600 tons' daily capacity, built in 1902.

Before the rails are put into the heating furnace fins or slivers, resulting from flowing of the metal, are ground off with an emery wheel, as it is found that the metal composing such imperfections is extremely hard, and if rolled into the body of the rail distinct cleavage lines will remain and lead to slivering of the rail head under traffic. As each rail is drawn from the furnace it is passed through a set of revolving wire brushes, to remove scale before the first pass through the rolls, and in advance of the last pass the scale is removed by a jet of steam. It is found that the chemical composition of the rails remains practically unchanged and it is claimed (on good grounds) that the rolling which the metal receives at the comparatively low temperature actually improves the wearing qualities of the rail. Data of rails in service have verified this claim. The loss of metal from oxidation in heating and rerolling amounts to about 1 per cent, and the entire loss from the rails, including the crop ends, amounts to from 6 to 10 per cent, but usually 7½ or 8 per cent, in weight of the metal rolled—that is to say, the number of tons of serviceable rails returned from the mill will fall 7½ or 8 per cent short of the number of tons of rail sent to the mill to be rerolled. Of this shortage about 6 per cent is returned in crop ends. The charge for rerolling has been $5 to $6 per ton.

Some of the roads which have made use of rerolled rails are the Chicago, Milwaukee & St. Paul; Atchison, Topeka & Santa Fe and the Wabash. The road first named began using rerolled rails in main track that were rolled principally from rails weighing originally 67 and 75 lbs. per yd. The 67-lb. rails were worn down to about 65 or 65½ lbs. per yd., and were rerolled to a 60-lb. section, as shown by the dotted lines in Fig. 496, reproduced from a full-size drawing taken from templets of the rails. The full line shows comparatively the original section of the rail, or what it was when first laid in the track. It will be noticed that the shape of the rail has been changed somewhat by the rerolling process, the web of the new rail having straight instead of curved sides, and the sides of the head being vertical instead of sloping. The hight of section is decreased slightly, resulting in a slightly shallower and narrower head and thinner and narrower flange. Figure 497 shows comparatively the size and shape of section of rerolled rails weighing originally 75 lbs. per yd., the dotted line of course representing the rerolled rail. These rails had been worn to about 72½ lbs. per yd. and were rerolled to a 67½-lb. section. It will be noticed that all parts of the rail are reduced somewhat in size, the head being slightly shallower and narrower, the web and flange slightly thinner. It would have been equally as feasible to have retained the original depth of section by narrowing the head and other parts to greater extent. In both cases the fishing angle remains the same, but the rerolled rail provided for a slightly deeper angle bar of standard size. The general practice in laying rerolled rails is to use new splice bars, but, if desired, the rail may be rerolled to fit the old bars again. If the rail is curve worn the rerolling process will transfer metal from one side of the head to the other, to balance the section. In some cases the rail has been rolled to a section ⅛ in. deeper than that to which it had been worn.

A desirable feature of the rerolling process is that the loss in cross section beyond what is actually required to form a new section of maximum size is gained in elongation of the rail. Thus, some of the 30-ft. rails rerolled for this road were returned from the mills 32 ft. in length, while others were cut off at 30 ft. To give another illustration of the result of rerolling, in this respect, the net gain in length in a lot of 16,007 rails rerolled was 7350 ft., and the reduction in section was from an average of 75.27 lbs. per yd. to a uniform weight of 67.7 lbs. per yd. The length at which the rerolled rails are cut in the practice of this road depends somewhat on the location of the old bolt holes. It is not permitted to cut the rail so that an old bolt hole comes between the end and the first hole to be drilled, but the rails may be cut through an old bolt hole, providing that not more than half of the old hole remains in the end of the rail. It is also required that no hole newly drilled shall meet one of the old holes, which are made somewhat oblong by the rerolling process. The experience which this road has had with rerolled rails has been quite satisfactory. Some of the rails rerolled from the original 67-lb. rails, above referred to, laid in the Muskegon yards of the road at Milwaukee, Wis., where traffic is very heavy, lasted better than any other rails which had been in service in that place. In 1902 this company had about 50,000 tons of rerolled rails in the track.

The Atchison, Topeka & Santa Fe Ry. began using rerolled rails in 1898. Some of the rails then used weighed 60 lbs. per yd., and were rerolled from a rail the original weight of which was 66 lbs. per yd. The larger quantity, however, weighed 65 lbs. per yard and were rolled from rails which originally weighed 71 lbs. per yd. and had been worn down to 69 or 70 lbs. per yd. These rails had deteriorated to the point where renewing became a necessity, and no old rails were taken up expressly for the purpose of rerolling. In 1902 the Coast Lines of this road were using 307 track miles of rerolled rail, and the experience had been quite satisfactory. The rerolled rails had worn much better on the curves than the original rails. The percentage of breakage had been a little higher than with new rails, but not to an extent that gave cause for alarm. The Wabash R. R. has used a considerable tonnage of rerolled rails in main track, the first being laid in 1898. Of this rail part was of 63-lb. original section, rerolled to 58 lbs. per yd., and more were rails of 70-lb. original section, most of which had been damaged by improperly counterbalanced locomotives running at excessive speeds. In 1904 several thousand miles of track on various roads had been laid with rerolled rails. As an experiment, with a view to improve the wearing qualities of the metal, the Baltimore & Ohio and Wisconsin Central roads have each had 1000 tons of new 85-lb. rails rerolled to 80-lb. section.

175. Rail Trimming.—When iron rails were used in main tracks the battering at the joints was so excessive that the rails usually became unserviceable from this cause long before the head along the intermediate portion was worn down sufficiently far to call for a general renewing of the rails. It was, therefore, considered extravagant to scrap the rails for this defect alone, and it came to be quite generally the practice to trim the rails by cutting off the battered portion at the end and then lay them again in the track in the course of ordinary repairs. Rails shortened in this manner were continued in service until the head was worn down to the allowable limit or until the ends became battered again, or, perhaps, again and again. The work of cutting the rails was quite frequently performed by the section men, with hammer and chisel, but when large quantities of battered rails had accumulated they were loaded up and sent to the shops to be trimmed and drilled for bolt holes. As steel rails and angle-bar splices came into use, the battering of rails at the ends, on any such scale as had been the case with iron rails, ceased to be a trouble with trackmen. In course of time, however, slight battering or surface bending developed in steel rails at the ends, in some cases, due to one or all of several causes, among which may be mentioned flowing of the metal, owing to inferiority of the product and increase in weight of locomotives and car loading; excessive allowance for expansion, failure to keep the joint splices tightly bolted and failure to keep the track in proper surface at the joints. With rails of good quality, properly spaced and maintained in fair surface, battering of the head at the ends is seldom the case, but after years of service it is quite common experience to find the under side of the head considerably worn by the splice bars. Such is quite likely to be the case where thin splice bars are used or where the duty of keeping the splices tightly bolted has not received close attention. With splice-worn rails it is impossible to secure a close fit, even with new splice bars, so that if this defect or battered or surface-kinked ends exists there is no remedy except amputation,

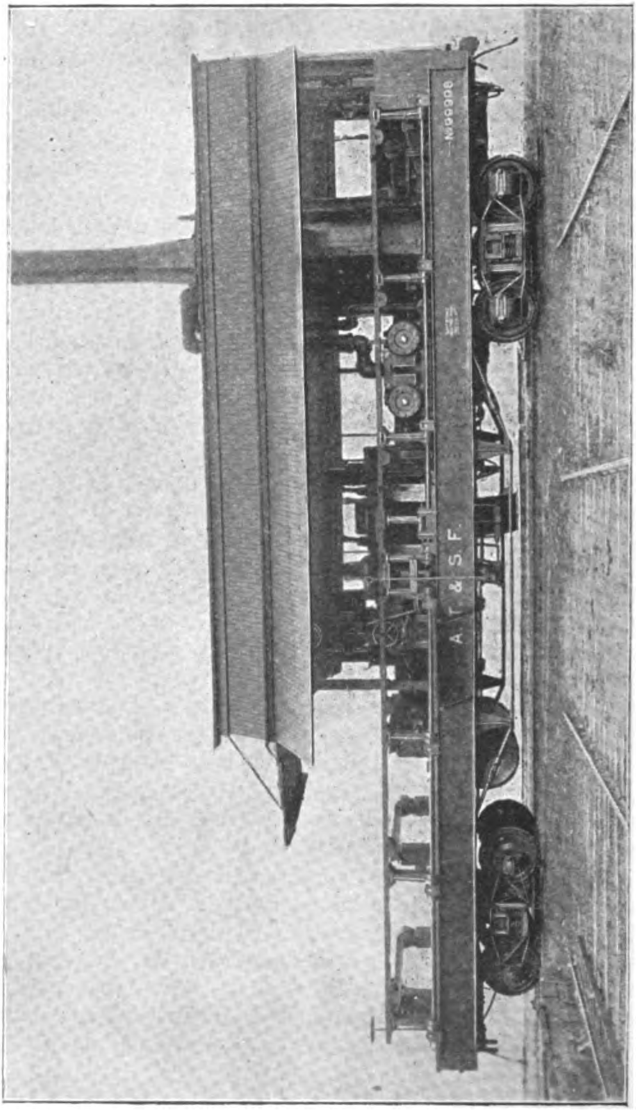
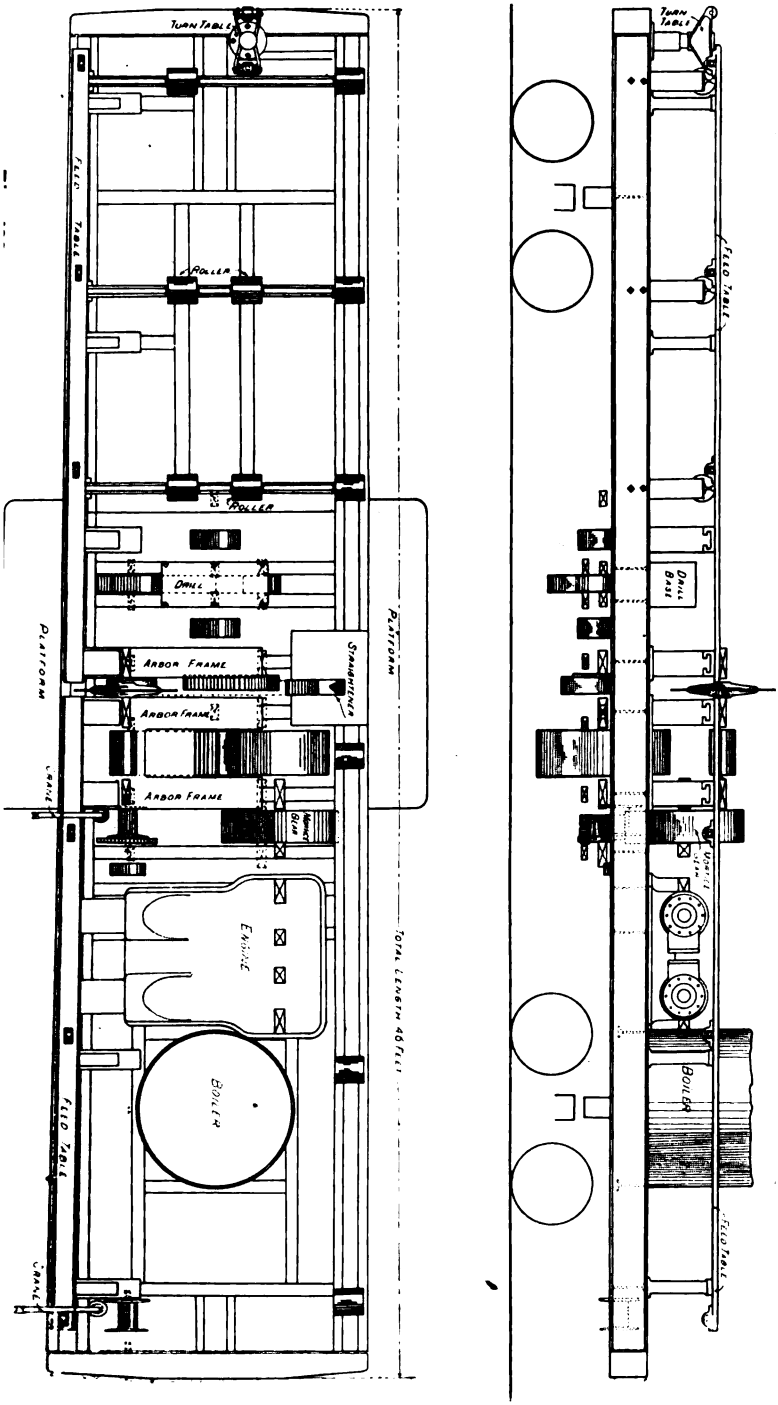


Fig. 498.—Portable Rail-Sawing Mill, Atchison, Topeka & Santa Fe Ry.

if it is expected to obtain further service from the rails in main track with economy in maintenance expenses. As the result of experience resort to trimming the ends of the rails has come to be the practice on a number of roads, particularly where rails are taken from the main line to be laid on branch lines.

The Michigan Central, the Atchison, Topeka & Santa Fe and some other roads have portable plants for trimming rails, the necessary machinery for sawing and drilling the rails being contained on a single flat car, vith auxiliary devices for lifting the rails from the incoming cars, and kidways for assorting the rails after they have been trimmed. The plant s set up at convenient points along the line, so that the cost of transporting he rails requiring treatment does not so largely affect the economy of the cheme as it otherwise would. The portable mills on the two roads named



are constructed alike and are operated in about the same way. Figure 498 shows the general appearance of the A. T. & S. F. mill and Fig. 499 the plan and elevation drawings. The car upon which the machinery is carried has a length of 46 ft. and a width over all of 10 ft. The car body is constructed in a very substantial manner, the frame consisting of 20-in. steel I-beams and channels thoroughly fitted and riveted together. The car body is carried upon two 4-wheel trucks of special design, to support the great weight, which, including the car and machinery, is 57 tons. The boiler is 10 ft. high, 63 ins. in diameter, with submerged flues 2 ins. in diameter. The engine operating the machine is of the horizontal type, of special design. It has double cylinders, 12x14. ins. each, and jacketed. The engine is connected directly with a mortise gear 48 ins. in diameter, which drives a cut steel pinion 20 ins. in diameter, thereby imparting a countershaft speed of 380 revolutions per minute. Upon this shaft is the band wheel driving the saw arbor. From the same shaft a 6 or 8-spindle drill is operated and, when necessary, the rail straightener. The disc or saw used in cutting the rails is 42 ins. in diameter and runs at 2000 r. p. m. About 150 h. p. is required to do the work properly. At the front side of the car (the near side in the illustrations) is arranged the feed table for conveying the rail to the saw. This table is constructed of steel channels, the channel side being placed upward and supported on arms keyed to a shaft journaled near the car floor. Within the channel are rollers for shifting the rail. The feed table is divided at the saw into two sections, and each section is operated by an air cylinder. For holding the rail securely while it is being fed into the saw there is a clamping device operated by an air cylinder provided with a quick release valve, as are also the feeding cylinders of the table. The rail drill is double, having three or four spindles on each side, provided with automatic or hand feed, as desired. These drills are independent and are connected by friction clutches to the main countershaft. Among the various miscellaneous machines included in the outfit is a steam turntable, upon which the rail is placed after one end has been drilled, so that it can be swung around for drilling the other end. There is a double rail clip hoisting mechanism for transferring the rails from the car to the feed table and systems of rail rollers for moving rails from one position to another. There is a water pump and tank for the use of the saw disc and for the drills. The machinery of the car is covered by a cab extending over two-thirds of its length, provided with swinging and sliding doors, so that all the machinery may be securely housed when not in operation, or while in transit from point to point.

The machinery for handling rails to and from the mill, as arranged on the Michigan Central R. R., is made clear in Fig. 500. The mill is placed on side-track between a siding for receiving the incoming rails, on the one hand, and a series of skidways or platforms for receiving the rails after they have passed the machine, on the other hand. It will be noticed that these skidways are graduated in width, the purpose being to receive the rails of shorter length on the skidways toward the left. These skidways hold about 100 rails each, in one tier. Just beyond the skidways there is a track for the cars upon which the outgoing rails are loaded. The operation of the mill may be described as follows: The car containing rails to be trimmed is placed at the front side of the mill. To begin with, the rail is seized near its two ends by the clips of two pneumatic cranes (Fig. 499) and lifted to the feed table. After the rail has been securely clamped to the first section of the feed table it is pulled against the saw, when it is swung back and run ahead past the saw to the other

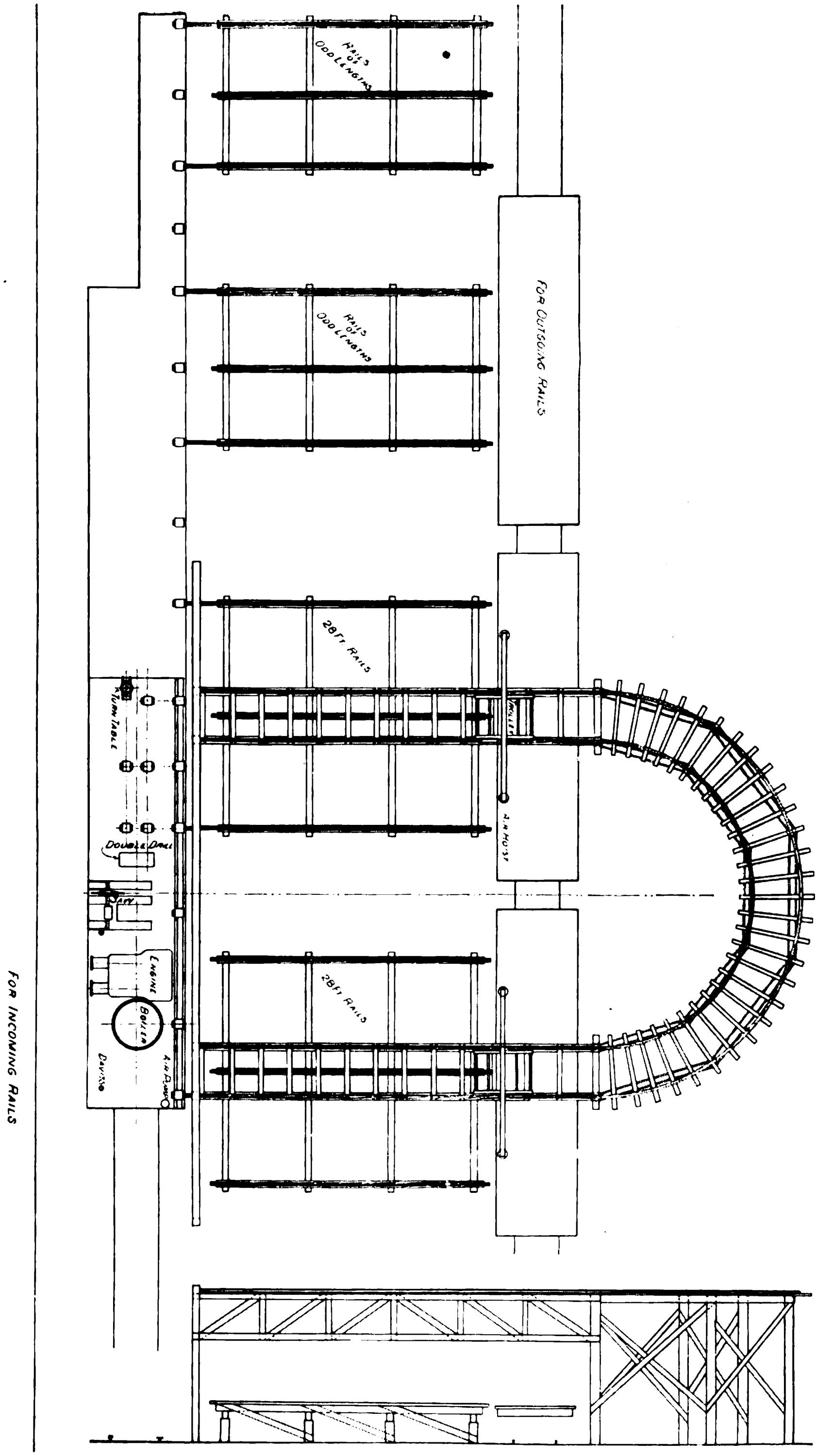


Fig. 500.—Arrangement of Portable Rail-Sawing Mill and Skidways, Michigan Central R. R.

section of the feed table, against a gage stub. In this position the rail is clamped and the other end is taken off; meanwhile the first section of the table is receiving another rail. Both ends of the rail being cut, it is then slid upon the storage space between the feed table and the first drill. It is next slid over to the drill and drilled. One side of the double drill does the drilling at one end of the rail, after which the rail is turned by the elevating steam turntable and the other end is drilled at the other side of the drilling machine. From the drills the rail is slid upon the long line of rollers (Fig. 500) for distributing to any of the skidways, its length determining the skidway to which it belongs. Unless the rail has to be straightened this ends the process, so far as the mill is concerned.

The means for transferring the rails from the skidways to the cars, or in handling the rails over for the purpose of matching, is very conveniently arranged. As will be seen in Figs. 500 and 501, there is an overhead structure or bridge, trussed over the skidways and loading track and trestled outside the track. The two trusses of this bridge extend over two skidways and are joined by a semicircular portion outside the loading

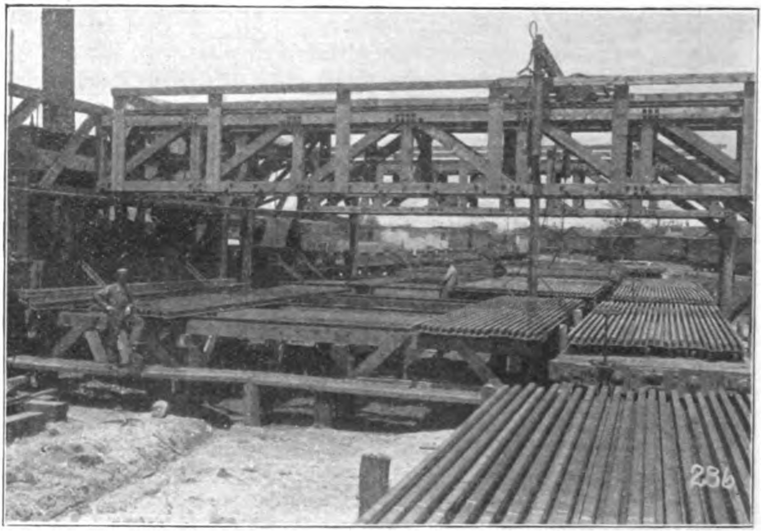


Fig. 501.—Skidways, Trolley and Air Hoist.

track. On this bridge there is a tramway carrying a trolley, which in turn carries a cross beam, on each end of which is an air hoist for lifting the rails. The trolley and hoists are operated by two men. To the piston of each air hoist there is fastened a chain with a rail clamp attached, for picking up the rails. After handling the rails on one of the skidways the trolley is run around the semicircle to the other skidway, as shown. The two skidways opposite the mill are intended for 28-ft. rails, which constitute the larger portion of the rails which leave the mill. Rails of odd lengths are run to the other skidways, where they are held until enough accumulate to furnish a car-load. On the A. T. & S. F. Ry. no rails are trimmed to a shorter length than 24 ft. The force necessary to handle the plant successfully is constituted as follows: One foreman, 1 engineer, 1 fireman, 1 sawyer, 2 drillers, 2 rail handlers at drill, 1 caliperer, 4 chippers, 2 men to load and 1 watchman; or a crew of 16 men, all told.

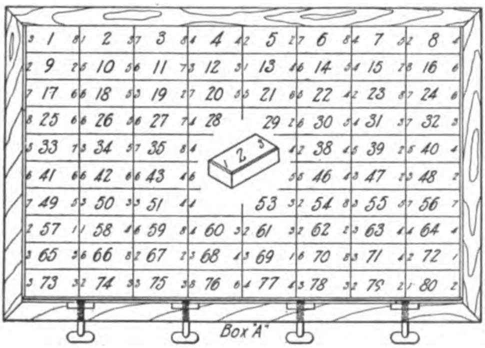
The overhead structure or tramway is arranged so that it may be readily taken down and shipped with the mill and erected at a new point of operation with but little trouble. A portable mill of later design is 59 ft. long and has an additional double drill, which dispenses with the steam turntable, so that opposite ends of the rails can be drilled at the same time by the two drills, thereby avoiding the necessity of having to turn the rail, as in the mill here described, wherein it has been found somewhat difficult to make the drilling operations keep up with the saw. In very fast work the rails are trimmed at the rate of one per minute. At the A. T. & S. F. mill two trolleys are employed—one over each skidway opposite the mill—and the framework supporting the trolleys is of riveted steel trusses and columns. The Chicago, St. Paul, Minneapolis & Omaha Ry. has a portable rail mill on a car 61 ft. long over all and 10 ft. 4 ins. wide. The equipment is similar to that above described, but includes two double rail drills 34 ft. apart centers. This mill will trim and drill 450 to 500 rails in 10 hours.

The Michigan Central trimming plant has been more or less in service since 1886 and has sawed several hundred miles of rail. After the rails are trimmed they are calipered as to depth of head, after which they are matched, numbered consecutively and so loaded that when the rails are taken off the cars the ends of the same depth of head will be together, so as to come in abuttal when laid. The calipering and matching idea originated with the late Mr. A. Torrey, chief engineer of the road, and is now recognized as a very important feature of successfully handling trimmed rails for relaying. Before this was done the variations in head depth of the rails as they were laid by chance made rough joints, and the use of trimmed rails was not satisfactory. Not more than 20 per cent of the rails in any lot trimmed are found to be equal in depth of head, and the difference in depth at the two ends of the same rail is often considerable.

Mr. Torrey's system of classifying the trimmed rails according to depth of head or hight, and in the order of laying, is simple but ingenious. The first thing that is noted is the itinerary of the cars on the loading-out track with respect to the direction in which they will head when arriving at their destination, the essential point being whether or not the rails in transit will get turned end for end from the way they are loaded. The sawing plant is so arranged that it is equally convenient to deliver the rails, after they are drilled, to either of the two skidways standing opposite (see Fig. 500). One of the skidways is set apart for rails to be laid on one side of the track and the other skidway for rails to be laid on the opposite side. In other words, if the track in which the rails are to be laid lies north and south, then one of the skidways will receive the rails for the east side of the track and the other skidway the rails for the west side. The rails are then delivered to the skids so that they will come reversed side to gage when laid; that is, the side of the rail head which stood to gage when the rail was first in service will come on the off side when the rail is relaid. As the burr from the sawing is clipped from the rails on the skids they are shoved along toward the loading track and arranged side by side, workwise, and chalk-marked consecutively from 1 to 80. The head at both ends of each rail is then calipered to the nearest 64th of an inch, record of which is taken, and then 60 rails from each set of skids (enough for a car-load) are selected and renumbered in the order in which they match end to end. They are then loaded upon the cars in this order, beginning with rail No. 60. A card is tacked upon the car indicating on which side of the track the rails are to be unloaded, and also indicating to which car-load for the same side of the track this car is the successor.

The foreman who unloads and distributes the rails at their destination sees that they are taken off the car in proper sequence—that is, from No. 1 to No. 60 seriatim, or in the reverse order from that in which they were loaded. The process of loading and unloading the rails is as simple as winding up a ball of yarn and then unwinding it: if the numbers are regarded there is no chance of getting the rails mixed up.

The system for recording the depth of the head at the ends of the rails and renumbering the rails in the order in which the ends match is as follows: A boy is given a shallow box in which are 80 sawed marble blocks $\frac{3}{4}$ in.x$1\frac{1}{2}$ ins. in size. The marking on the blocks is done with a common lead pencil, and before the boy begins work on a new set of rails he erases all the old pencil marks from the blocks and numbers them consecutively from 1 to 80, as shown in Box "A," Fig. 502. Each block represents one of the rails on the skidway, and the box is used like a map, the proper edge signifying the east or north end of the rails, as the case may be. As the boy calipers the east end of the 80 rails he marks the reading of the instrument for each rail on the east end of the block numbered to correspond to that rail; and when he calipers the west end of each rail he likewise marks the west end of the block which corresponds to that rail. When both ends of the rails have been calipered and recorded in this manner the



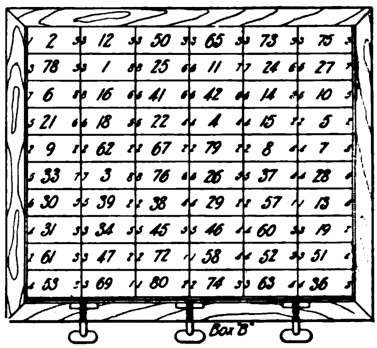


Fig. 502.—Matching Box for Classifying Rails—Fig. 503.

boy sits down and "plays dominoes" with the blocks into an empty box, until he gets 60 to match, as shown in Box "B," Fig. 503. To play the "game" fairly he must evidently keep all the blocks lying in the same direction, and not try to make them match by turning any of them end for end. It then remains only to renumber the rails to identify them with the matched arrangement in Box "B." This is done by painting on the middle of each rail the figure which represents the consecutive number of the space in which the block corresponding to that rail is found: figure 1 is painted on the rail marked 2 in chalk, figure 2 on the rail marked 12 in chalk, figure 3 on the rail marked 50 in chalk, and so on. The rails are then loaded in the order of the painted numbers. The 20 rails which are not matched or not loaded remain on the skids and form part of the next set of 80. The boy keeps a record of the caliper reading of the tail end of rail No. 60 in each car-load, and in starting the domino game for the succeeding car loaded from the same set of skids, he uses a block the head end of which is marked with the same figure.

The calipering instrument used in this work is shown as Fig. 504. The lower jaw is shaped to fit the fishing surfaces on the under side of the rail head and it carries two set-screws which can be adjusted to hold the caliper central with the web. The readings of the instrument correspond to differences of $^1/_{64}$ inch in depth of head. In using the caliper it is generally clamped to read 0 when it fits the head of an unworn rail of the original section, as then the readings on the worn rails will be the smallest numbers possible. Where the sawed rail is to be used with angle-bar splices account is taken of the depth of head only, as hitherto described, but if a type of splice is used which supports the rail at the base, then the total depth of the rails is calipered and they are matched on that basis. For such work a different caliper from the one here described is used.

By this plan of selection the sawed rails make as smooth joints as new rails—some say smoother than new rails rolled in mills where the rolls are permitted to run too long without dressing. The cost of sawing and handling, including matching, averages about 75 cents per gross ton. The product of the saw is found to be satisfactory when laid with new joint fastenings, but not when the old joint fastenings are applied. On this road the portable nature of the machine is found to be advantageous because of the fact that the company quite frequently finds itself short of equipment for hauling rails over long distances. At one stand where the Atchison, Topeka & Santa Fe mill was in operation, on the middle division of the road, it was used in trimming 6556 tons of 61-lb. steel rail. The rail handled was

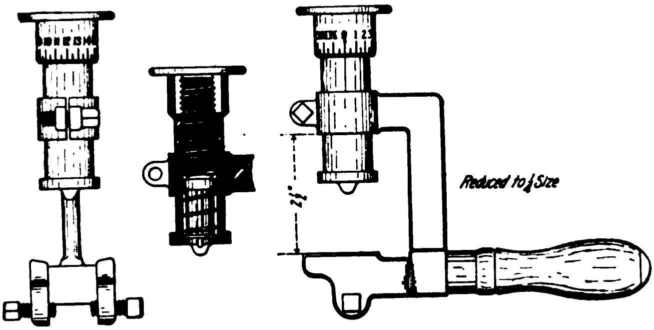


Fig. 504.—Rail Head Caliper, Michigan Central R. R.

in fairly good condition when taken out, notwithstanding that it had been in the track about 18 years. The rails were battered down $^1/_{16}$ to $^3/_{16}$ in. at the ends and the majority of them were splice worn under the head; in some cases also there was appreciable wear on the base. As a usual thing only 12 ins. was cut off each end, so that most of the trimmed rails which were returned from the mill were 28 ft. in length. The mill was run a total of 99 days, during which time it worked 784 hours, and the following is a list of the items chargeable to the expense of operation: Coal, 289 tons, $511.69; cost of repairs, including material, waste, etc., $410.83; cost of labor to operate the plant, $4138.69; total $5061.21. The average cost per ton for sawing, drilling, calipering and loading was, therefore, 77.2 cents. About 500 tons of crop ends were obtained as a by-product of the work, which were sold for $3800. When the mill is run at its full capacity it will cut rails for a mile of track per day and the proceeds from the sale of crop ends will nearly pay the cost of operation.

Figure 505 shows the end of a rail selected as a sample from a lot of 6000 tons of steel rails trimmed and redrilled for the Pennsylvania R. R. some years ago at a private mill in Wheatland, Pa. These rails had been in the main track of this line for fifteen years, the original weight having been 70 lbs. per yard. The rails had lost about $^1/_{16}$ in. in hight, pretty uniformly. The illustration shows the application of a straightedge to the top of the sample rail, disclosing that the rail end had been bent or worn downward $^3/_{16}$ in. The vertical white mark shows how much of the end had to be cut off to reach the uninjured portion of the rail. The rails as originally drilled were spliced with four bolts, but in drilling them after the shortening process, three holes were made in each end, for a 6-bolt splice. After trimming the rails they were sorted and kept together in sizes within a variation of $^1/_{32}$ in. in hight. In the lot of 6000 tons it was found that more than 80 per cent of the rails were of one hight. By the arrangement at this mill, operated by the Holland Company, of Pittsburg, Pa., the mill people took the rails from the cars, sawed, calipered, drilled and reloaded them, and disposed of the crop ends and applied the proceeds of the same to the expense of sawing. The plant comprised two toothed saws, 42 ins. in diameter, running at a peripheral speed of about 4 miles per minute. The rails were sawed dry—two rails at the same time by each saw. As a matter of record a rail was cut off in 8 seconds. Special apparatus had been arranged for lifting the rails to and from the cars and other parts of the equipment were adapted equally well to facilitate the work.

The Norfolk & Western Ry. has at Roanoke, Va., a stationary rail-sawing mill, equipped with a 46-in. friction saw, two three-spindle drills and a rail straightener, and large quantities of steel rails which have been removed from the main line for the purpose of relaying the track with heavier rails have been trimmed and straightened for use in branch lines. The time required to cut off a 75-lb. rail is from 15 to 20 seconds and the

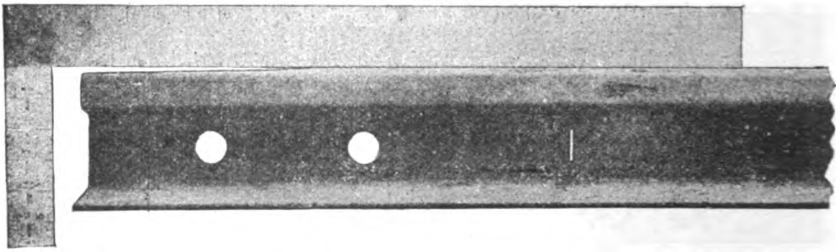


Fig. 505.

time required for drilling three holes in each end for splice bars is from 30 to 40 seconds. The mill has a capacity for sawing, drilling and straightening (such rails as require straightening) 300 rails in 10 hours, and the cost is about 12 cents per rail. There are rollers and skidways in rear of the mill, on which the rails are sorted and from which they are loaded to the cars. The Chicago, Milwaukee & St. Paul Ry. has a stationary rail trimming plant at Savanna, Ill. The Pennsylvania R. R., which has access to four stationary cold-sawing plants, has used trimmed rails in its light-traffic lines extensively. On the Western Railway of France the trimming of rails with battered ends for relaying is done by hand. The tool used is a hack saw, the blade of which lasts on an average for two cuts. Usually the rail is cropped 14 ins. at each end; that is, the rail is shortened 28 ins.

176. Track Elevation and Depression.—Track elevation or depression is generally understood to mean the work of raising or lowering track to a new level or grade line, on the same or practically the same location. Either term implies change of elevation, but the operations performed may or may not involve the lifting or lowering of the old track: a new track is sometimes built at the changed elevation and the old track is then abandoned and taken up. Of late years such work has assumed considerable importance, which will increase with time, owing to the growing tendency toward grade reduction and the abolishment of grade crossings in and about cities and in thickly populated districts. The work also derives importance from the engineering problems involved, which are usually of a high class and not infrequently very intricate. As a rule, the simplest problems attaching to such work are found in the country, where there are fewer highway crossings to deal with and where train movements are less frequent. Aside from the surveying the work in such locations is largely of the nature of track work, as a rule, while in the cities it is a combination of track and bridge work, and quite frequently it also involves the lowering of sewers and gas and water mains at the street intersections. While local conditions determine that the general work of track elevation or depression in any case is a special problem there are many details of the work, especially with reference to methods of handling the track, much the same or similar in nearly all cases, which are worth considering. It is to be remarked that while track elevation work is usually classed as engineering, skillful trackmanship (which is none the less engineering) is one of the essentials to the economical performance thereof.

The work of reducing grades on an old location usually consists in depressing the track at summits and elevating it in the hollows, the material excavated from the cuts being hauled to make the fills in the hollows. In cases where the quantity of excavation is not sufficient to do the filling it is customary to begin the embankments by scraping material from the side of the right of way with teams; or in some cases the central core of an embankment is put up by team work and a track is laid, from which material can be dumped from cars to widen out the earthwork to standard dimensions. If borrow material must be used to make the fills it will sometimes pay to purchase land on the inside of some curve, in cut, and take out the material with a steam shovel, thus making room to ease the curvature. The facility with which such operations can be carried on while maintaining the traffic of the road depends a good deal upon whether the road is single or double track. Large quantities of excavation are, of course, best handled with the steam shovel, unless the material is rock; and with the massive machines of modern construction it is frequently considered economical to handle even that material with steam shovels, after loosening up the rock by blasting. Where train movements are frequent, it will usually be found advisable, in deep cutting and high filling, to shift either the old track or the new grade line laterally a sufficient distance to enable the fill to be made from a temporary trestle of cheap construction, so that traffic on the main line need not be disturbed. The economy obtained in dumping the filling material from a trestle, as compared with the method of raising the track by stages and supporting it with the filling material, is found partly in the large saving of labor required in handling over the material; for every time the track is raised it must be at least roughly ballasted before trains can be permitted to pass. By the latter method there is bound to be at least some delay to the trains; a great deal of time is lost to the labor in waiting for trains to arrive and get out of the way; and as far as the construction of the fill is concerned, a great deal of labor goes for naught in continually preparing for the passage of trains. In dumping material from a trestle no hand labor is required until it becomes necessary to dress out the material at the top of the fill. In work of this kind carried out on the Illinois Central R. R. between Fulton, Ky., and Memphis, Tenn., the fills in various places were made from temporary trestles, as shown in Fig. 506, the new grade line being offset 18 to 50 ft., so that all portions of the fill could be constructed without interfering with main-line traffic. The top of the trestle was 3 ft. below the new grade line, so that the track in its final position would be

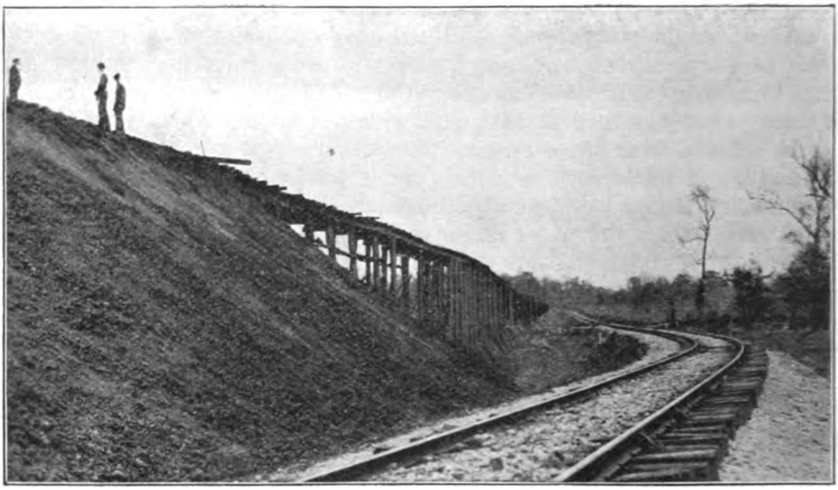


Fig. 506.—Raising Grade by Filling from a Temporary Trestle.

clear of the timber-work of the buried trestle. The material was handled by ordinary methods, being loaded in dump cars and run out onto the temporary structure by locomotives, on narrow-gage tracks in some instances and on standard-gage tracks in others.

In depressing a single track on the old location it is most commonly the practice to shift the track laterally a sufficient distance to permit the steam shovel to excavate the cut, thus providing for the traffic to pass undisturbed, meantime, and then to build a new track through the cut on the new grade, connect with the old track at the ends of the cut, and abandon the old track over the top. This was substantially the method followed in some very extensive work at grade reduction on the Chicago Great Western Ry., near Holcomb, Ill. The work involved a change of grade over a distance of five miles, with some deep earth and rock cutting at a point known as the "Holcomb Cut." At this place the grade was reduced from 1 to $\frac{1}{2}$ of 1 per cent, and by constructing overhead bridges across the cut the company was enabled to avoid five grade crossings with highways. The principal cut was one mile in length, with a maximum depth of 45 ft., the average depth for a distance of 1000 ft. being 40 ft. At one end of this cut the main line and some yard tracks had to be moved over to allow for necessary excavation, while at the other end the cut was excavated at some distance aside from the old location. While the cut was being made the trains used the old track over the top of the hill, and the new track was not laid through the cut until after its completion. The bulk of the material taken out of the cut was hauled in side-dump cars and used to raise the grade of the line to the west of the hill, the maximum haul being four miles. This material was handled with cars and locomotives of 3-ft. gage and the method of elevating the track was to widen out one side of the embankment at a time, by unloading from the side-dump cars, raising that side about 5 ft. above the main line; and then to throw the main line over on the new grade, when the other side of the fill would be widened out and raised 10 ft., or 5 ft. above the main line again. Temporary bridges were put in at the highways, where necessary. This method of procedure was repeated until the main line was thrown to final grade, when the balance of the embankment was brought to grade and the main line thrown to the center of the roadbed, which was finished off 24 ft. wide at sub-grade.

Another method that is commonly followed is to cut through with the steam shovel close beside the old track, completing the slope of the cut on that side, as illustrated in Fig. 507, and then to shift the track into the depression so made and later cut out the old bed and form the slope on the other side. Where the traffic is light the main line is sometimes used for the loading track, but if the traffic is heavy it is usual to build an extra track through the cut, either for a loading track, as shown, or for the traffic. In reducing the grades of the Grand Trunk Western Ry. the traffic through cuts that were being lowered was provided for on a "detour" track built at the side of the old main line, along the foot of slope, or by digging into the slope with pick and shovel a few feet in some places where it was necessary to make room. The old track would then be used for the loading track while one side of the cut was being lowered. By blocking up under the steam shovel as it progressed an excavation 15 ft. deep, in a single cutting, was sometimes made in this way, the material being loaded upon flat cars standing on the old track, as stated. The two tracks on the upper bench would then be thrown down into the new excavation and the steam shovel would take out the other side of the cut, the near track being used to load upon and the off track for traffic. In some locations, however, a new track was built in the bottom of the first excavation and ballasted up for the traffic, and the old main track thrown down to load upon when the steam shovel was ready to begin work on the other side. In that case the "detour" track was taken up.

Some characteristics of steam-shovel operation adopted by the St. Louis Southwestern Ry. in deepening cuts in grade reductions are shown in Fig. 508. The illustration shows the method of taking out the first cut in work of this character. The order of procedure is to throw the main track off the center as far as possible, through the cut to be lowered, this distance

Fig. 507.—Lowering Grade through a Cut.

usually averaging about 6 ft. The track so moved is still used as main track for passing the traffic, and at the same time is utilized as a loading track in connection with the steam shovel. After the first cut has been taken out traffic is diverted to the track previously used by the steam shovel, and the shovel is then put to work at taking down the other side of the cut; this operation being repeated until the desired depth is attained. In the particular piece of work illustrated by the sketch a summit cut having an original depth of 16 ft. was lowered an additional 16 ft. by the steam shovel, the first cut being 9 ft. in depth, as shown. In this case the new roadbed was graded to new centers to the right of the old line, and the tangents on each side were swung to a connection with a curve over the summit, after the same was thrown farther out to admit of the change. Under these conditions the material excavated from the right-hand side of the old track was in excess of that taken from the left-hand side, as indicated by the location of the new slope line. The summit was lowered the depth of 16 ft. with three cuts of the shovel, traffic being handled meantime without obstruction. The excavated material was hauled and dumped to raise the embankments over a distance of three miles on each side of the cut, resulting in a continuous ascending and descending gradient of 26 ft. to the mile over a distance of 6 miles, where a steeper grade had previously existed. In some places where work of this character was undertaken it was found to be advantageous to make the excavations on the inside of the curves and widen the embankments on the sharp existing curves, in order to improve the general alignment without having to shift the track very far.

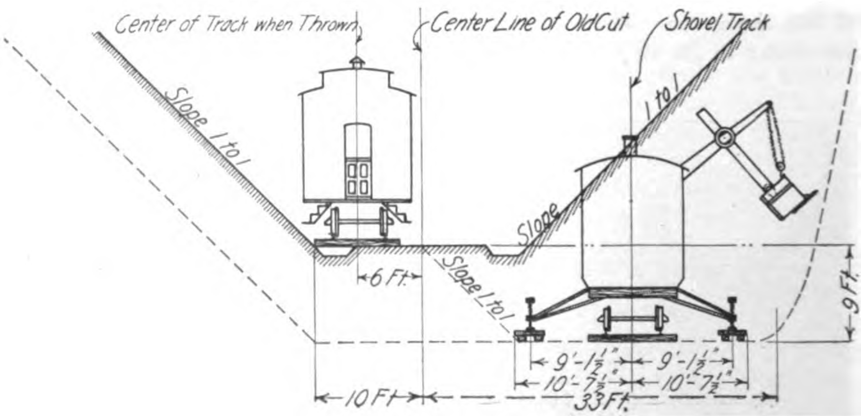


Fig. 508.—Method of Lowering Cut, St. Louis Southwestern Ry.

In elevating a double-track roadbed the inconvenience to the work in caring for the traffic is not so great as with single track, for one of the tracks may be abandoned temporarily, lifted 3 or 4 ft., filled in and roughly ballasted, the other track meanwhile carrying the traffic for both directions. The traffic may then be shifted to the higher track and the lower track lifted, filled in, the bank widened out on that side, and the track put in running order at an elevation of 3 or 4 ft. higher than the other track; and thus the embankment is carried up, the traffic being shifted from one track to the other as the work of filling proceeds from side to side. The service track is sometimes operated as a single-track block between semaphore signals established temporarily beyond the extreme limits of the stretch of work, operators being stationed at these points, in telegraphic communication with each other and with the train dispatcher.

The same arrangement is sometimes applied to the elevation of a single track. Part of the time the service track is used by the work trains, from which the material is unloaded and placed under the raised track. If a telegraph operator be stationed at the steam shovel, or if telephone connection be had between that point and the nearest telegraph station, so that the whereabouts of the main-line trains can be ascertained, the movements of the work trains can be much facilitated.

After the filling has been brought to the final grade the tracks are thrown to the permanent alignment and ballasted. It is not worth while to spend much time dressing off the ballast between the rails and on the shoulders, for on newly-made fills the track must necessarily settle quite rapidly; and not until some time has elapsed is it possible to maintain the track to an even surface at the desired grade. In lining the track, from time to time as the filling progresses, ordinary lining bars are found to be of but little use, being too narrow to obtain a firm hold in the loose material; and handspikes are usually substituted as being better adapted for the purpose. In the track elevation work of the Chicago, Burlington & Quincy Ry. the handspikes for throwing track were neatly made of oak 6 ft. long and of a section 3x3 ins. square for the first 2 ft. in length from the point, whence the stick was rounded and tapered to a size convenient for the grasp of the hand at the end. These handspikes had a crow-bar or wedge-shaped point.

In depressing double tracks it is usual to abandon one of the tracks and use it as a loading track for the steam shovel. After the first cut has been made this track can be thrown into the depression and serve as the loading track for a second cutting of the steam shovel, under the old bed. When the final grade is reached the track in the depression can be put in shape for the traffic and the steam shovel can be set at cutting out the remainder of the material to be excavated. In depressing three tracks at 12 ft. centers, over a stretch of 1¼ miles on the Chicago, Burlington & Quincy Ry., near Kirkwood, Ill., the middle track being a passing track, the method of doing the work was to throw the outside tracks outward to 14 ft. centers from the middle track, and then to cut down between the tracks by hand to a depth of 3 ft. The middle track was then taken up and the remainder of the excavation made with a steam shovel, using one of the tracks for traffic and the other for loading the material, until the middle core was taken out, when first one of the tracks was shifted into the excavation and put in running order, and then the other. Later on excavation was made for the third track, the passing track this time being placed on the outside, so as to enable the straightening of the two main tracks.

Change of Grade in Cities.—The elevation and depression of tracks in cities has received most attention in and about Boston, in Philadelphia and in Chicago; but especially in Chicago, where several hundred miles of steam railroad tracks have been elevated, resulting in the abolishment of several hundred grade crossings with streets. As the work has been carried out in that city the tracks pretty generally have been elevated about 10 ft. and the streets depressed at the subways to give a clear headroom of 12 ft., except in subways carrying street car tracks, in which case the clear headroom has been made 13½ ft. Retaining walls of stone masonry or concrete have been used where the width of the right of way has not been sufficient for a fill with natural slopes. The filling material in nearly all cases has been sand, of whitish color, excavated from sand dunes in Indiana and hauled about 35 miles.

The controlling feature in the work of elevating tracks in cities is the erection of the bridges (temporary and permanent) at the street intersections, which, in connection with the frequency of the train movements and the number of tracks to be elevated on the same roadbed, are the conditions which determine the method of handling the tracks. In nearly all cases the plan followed has been to abandon part of the tracks temporarily while they are being elevated, diverting the traffic to the remaining tracks, partly or wholly, or partly or wholly to tracks built temporarily to carry the traffic. Thus in elevating $4\frac{1}{2}$ miles of four-track road on the Providence division of the New York, New Haven & Hartford R. R., in Boston, in 1895 and 1896, strips of land were purchased on each side of the original right of way (66 ft. wide) and temporary tracks were laid thereon to carry part of the traffic. Over part of the way two high-level tracks were also laid, on trestle, to carry the traffic, this trestle being so located that it was afterwards filled in and made part of the elevated roadbed. The tracks were elevated 18 to 20 ft. above the original grade line without closing the streets and without interfering with the trains, which averaged 206 per day. The two westerly tracks were raised first, the retaining wall and the filling on that side being carried up simultaneously. The abutments for the bridges were built across half of the street at a time, and the bridges were completed and the tracks laid thereon and put in running order, so that trains could be moved over the two elevated tracks before taking the other two tracks out of service. Temporary trestles were used to make the approaches to the bridges on the tracks which were being elevated. After the two westerly tracks had been put in running order at the new elevation the east retaining wall was constructed and the two tracks on that side were taken out of service and elevated. A similar method was followed in elevating the two tracks of the St. Charles Air Line, between Clark street and Michigan avenue, in Chicago, in 1898. The retaining wall on the north line of the right of way (the tracks running east and west) was first laid, when a trestlework was constructed close to the wall to carry an elevated track. After the traffic was diverted to this trestle the retaining wall on the south side of the right of way was constructed, and the space between the retaining walls was filled with slag from gondola and side dump cars, first filling under the trestle and then widening out the embankment by building an additional track and dumping the material therefrom. Before the tracks were ballasted the stringers and caps were removed from the trestlework.

In elevating eight main-line tracks of the Illinois Central R. R. between Forty-seventh and Seventy-first streets, in Chicago, in 1892 and 1893, the work was begun on the east side of the company's right of way by the construction of a sand fill raised as high as was practicable in the middle of the blocks between the street crossings, with steep grades down to the crossings of the several streets, which had to be kept open for highway travel. Pile trestles were then constructed at the street crossings and one track was carried over the same, filled in and put in running order. In this manner the filling was gradually widened out toward the west and the tracks elevated, additional lines of trestle being built across the streets as the tracks were raised. The work of building the masonry abutments and the erection of the plate-girder bridges to replace the temporary trestles was an after consideration. In elevating the four tracks operated jointly by the Chicago, Rock Island & Pacific and the Lake Shore & Michigan Southern roads, in Chicago, two tracks were elevated together, in stretches over four blocks. The method pursued by these companies was to lift the tracks gradually, supporting them on blocking or cribs at the street crossings, until the full elevation was reached, when framed trestle bents and stringers were placed for the support of the track until the abutments were built and the plate-girder bridges erected. In some cases two of the tracks were first elevated to the full hight and put in service over bridges laid on abutments built in halves, and in other cases all of the tracks were first raised to the full elevation before the abutments were built or the bridges erected.

In the track elevation work of the Chicago, Milwaukee & St. Paul Ry., in Chicago (four tracks), the tracks were lifted to the final elevation in three stages, one track at a time, but all of the tracks more or less together, so that all the tracks were brought to the full elevation and supported upon temporary structures at the streets before the masonry work of the abutments was commenced. The method followed was to drive three-pile bents at the streets before the tracks were raised. These bents were located to span the abutment site at either side of the street, dodge the sewers, water pipes, etc., keeping within a span length of 15½ ft. These piles were then cut off at the elevation of the base of rail, and at the first lift, usually about 4 ft., the track was supported on two 12x12-in. caps (one on top of the other), upon which were laid the stringers and ties. The purpose of driving the piling for the support of the caps was to permit excavation for the depression of the street without weakening the support for the track. In the second and third stages of lifting the track, jacks were used under the uppermost of the two caps and at each stage the cap was supported by 12x12-in. posts, until the track was raised to the final hight and posts of the proper length were placed and braced to form framed bents. The piles used were second hand, 12 to 18 ft. long, some of which were tops cut from piles driven in the ordinary work of the road, the only requirement being that they should be sound enough to stand driving and last two years. Fir stringers 8x16 ins. x32 ft. long, were used, lapping by each other on the trestle caps. The posts were cut to standard lengths and this timber was used over and over, continuously, throughout all of the track elevation work of the road. The cost of this falsework per lineal foot of one track was $2.10, of which $1.30 was for labor and 80 cents for loss and deterioration of timber and iron. In order to facilitate the erection and removal of the timber the caps and sills were doweled to the posts and the brace planks were bolted. In this manner the track elevation work could progress independently of the masonry work and the erection of the plate-girder bridges. The abutments in all the bridges of this work were built of concrete. In elevating a two-track line of this company two temporary tracks were built at one side of the right of way to carry the traffic trains while the work of elevation was in progress.

In elevating the four tracks of the Pittsburg, Ft. Wayne & Chicago Ry., in Chicago, two tracks were abandoned and raised at a time. The method pursued differed from the foregoing, in that the bridges at the street intersections were erected, in place, on timber bents before the tracks were raised out of the old bed at the streets, although to some extent the tracks were raised in the middle of the blocks, under traffic. On portions of the line where bridges were so close that an appreciable elevation could not be had by raising the tracks in the middle of the block a cribbing of old ties, about 8 ft. high, was built to permit the two tracks which were being elevated to be placed at their full hight, the purpose of the cribbing being to retain the filling material which otherwise would have encroached upon the clearance of the adjacent running track. Tie cribbing was also constructed to serve as bulkheads to retain the filling at the ends of bridges until the abutments of the same were built. After two of the tracks had been elevated and put in running order over the permanent structures the traffic trains were diverted to them and bridges were put up for the other two tracks, which were then elevated. As far as possible the old ties forming the cribbing between the two middle tracks were dug out of the sand filling and removed as the third and fourth tracks were elevated.

In elevating the lines of the Chicago & Northwestern Ry., in Chicago, each track elevated was first raised to a summit in the middle of the block. The pair of girders for each (alternate) track were assembled at a distance, in a yard specially fitted up with derricks for the purpose, and brought to the crossing on flat cars, with the floor riveted up in position, complete, and the rails in place. Previous to the arrival of the bridge two piles would be driven on each side of the track to form

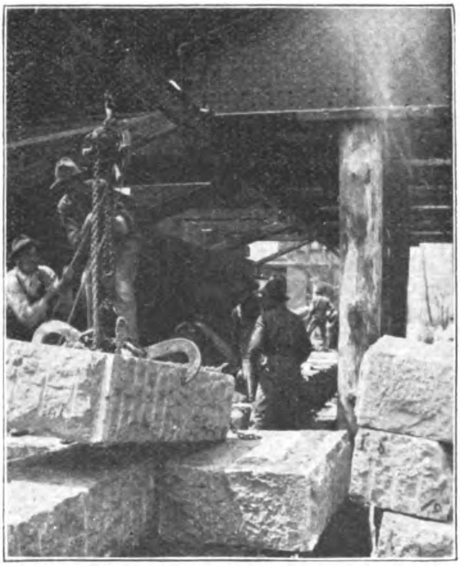


Fig. 509.—Trolley for Laying Stone, C. & N. W. Track Elevation.

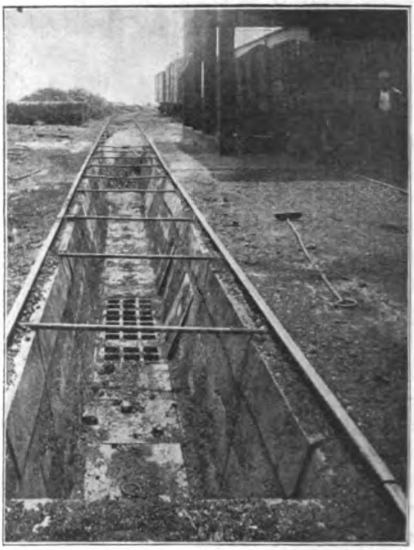


Fig. 509 A.—Cinder Pit for Conveyor Plant, Ill. Cent. R. R.

a two-pile bent of 9 ft. clear span, or a pier of four piles, for the temporary support of each end of the bridge while the abutments were being built underneath. Each pile bent was capped with two 15-in. I-beams, and the bent spanned the site of the abutment. In some cases the piles were cut off to place the bridge at an elevation of 7 ft. and in other cases to place it at the full elevation of 10 or 11 ft.; and in bridges of more than one span resting upon posts or columns the girders were unloaded from the cars directly to the posts, at the full elevation. Upon the arrival of the bridge it was jacked up on the cars, which were run between the pile supports, and let down upon the I-beam caps, and then the cars would be pulled from underneath. After landing the bridge on the pile supports in this manner, the track on the approaches to the bridge was raised, connected across the bridge and filled in, timber cribbing being placed to retain the filling at the abutment sites and at the high portions of the approach, at the sides. After a number of bridges had thus been placed and the approaches built on one of the tracks (of a three-track line) or on two of the tracks (of a five-track line) the traffic was turned onto the same. The work of track elevation and of placing the bridges thus progressed independently of the masonry work of the bridges, which was laid as best to suit convenience, at some time thereafter. The track at the middle of each block remained in a depression, not being raised as high as the bridges at the intersecting streets until the remaining parallel tracks were raised and filled in, thus avoiding the necessity for cribbing, which would have been necessary had the tracks been raised to the full elevation throughout the entire distance between the streets, since the slope of the filling material would have extended beyond the clearance line of the running track adjacent thereto. In elevating the five tracks of the Galena division of the road, three tracks, consecutively from one side, were abandoned and two retained in service. Bridges were placed on the first and third tracks and the intermediate floor for the second track was riveted in and all the filling made for the three tracks before traffic was turned over any of them. After traffic was turned onto the three tracks the other two tracks were abandoned, when the third pair of girders was placed and the intermediate floor put in. In elevating the three-track line on the Milwaukee division, the bridges were placed first for one of the outside tracks, which was elevated and put in running order, when the other outside track was abandoned, the bridges put in, the tracks elevated, and the intermediate floor riveted in between the bridges on the outside tracks. The stones for laying the abutments under the temporarily supported bridges were placed by a trolley running upon an 8-in. I-beam suspended from the lower flange of the girders to extend crosswise the bridge and over the middle of the abutment wall. The ends of this I-beam, which projected beyond the girders a sufficient distance to cover the length of the abutment, were held up by posts. The trolley arrangement straddled the web of the I-beam and ran upon the bottom flange. From the trolley was hung a Duplex block and fall which would hold its load at any point to which the same had been hoisted. Since the bridge seat casting was about 17 ins. high, all except the top course of stone could be lifted and run to place by this device, which is shown in Fig. 509.

A five-track line in Rockwell St., Chicago, consisting of two tracks of the Pittsburg, Cincinnati, Chicago & St. Louis Ry. and three tracks of the Chicago & Northwestern Ry., were elevated by methods much the same as those followed in the work of the C. & N. W. Ry., just referred to. To begin with, the bridges over four streets were erected for the two tracks of the P., C., C. & St. L. Ry., the traffic meanwhile being diverted to the three C. & N. W. tracks. After the filling had been completed between these four bridges and on the approaches the traffic was then handled over the P., C., C. & St. L. tracks, and bridges for eight blocks of the C. & N. W. tracks were erected and the track elevated to them. Traffic was then diverted to the C. & N. W. Ry. over these eight blocks and the elevation on the P., C., C. & St. L. extended four blocks on either end of the four blocks first elevated, thus making 12 blocks of completed work on these tracks. After diverting the traffic to these 12 blocks, the elevation on the C. & N. W. tracks was then extended eight blocks more, making 16 blocks in all. In this way the work progressed, using the tracks of one company while the work of elevation was being prosecuted on the tracks of the other. The average force was 300 men at raising and filling in the tracks and 200 men at putting in abutments and excavating and lowering the streets by contract.

Some very difficult engineering of a special character, encountered in changing the grade of tracks in the business centers of cities, including the depression of the Philadelphia & Reading Ry. tracks in Pennsylvania Ave., Philadelphia, and the elevation and depression of a network of tracks at Sixteenth and Clark streets, Chicago, is described in § 205, Supplementary Notes.

The best filling material for use in track elevation is sand, for many reasons: It is easily and cheaply handled, not only in loading and unloading the cars, but in putting it under the track; it does not become muddy or impede the progress of the work during wet weather, nor is its condition so changed during rainy weather that it cannot be worked to advantage, or so as to endanger the stability of the track; it serves as a fair material for ballast while the track is being raised; and it is readily compacted under the pressure of trains to form a firm embankment. In cities, therefore, where filling material for track elevation must usually be hauled from a distance, it is, if available in the locality, undoubtedly the most economical material to be obtained. The work of depressing the streets in subways under elevated tracks is usually performed with teams and scrapers, and the material obtained from such excavation is usually hauled around and dumped to form part of the filling material for the elevated tracks.

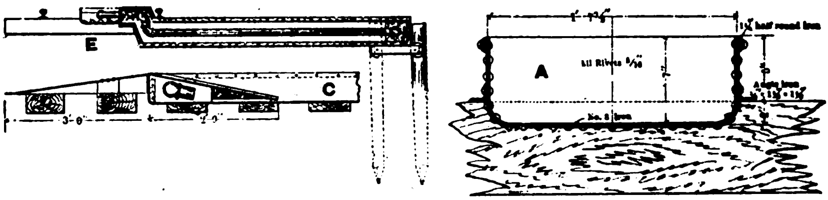


Fig. 516.—Track Tank, Chicago, Milwaukee & St. Paul Ry.

Most of the sand filling used in Chicago for track elevation work has been hauled in gondola cars and unloaded over the side of the car with hand labor. Where this has been done the trains have been unloaded from a track adjacent to the one being elevated, which was usually raised and blocked or otherwise supported at a good hight, so that the material as it was unloaded from the car was thrown to place under the track. In the track elevation work of the Chicago, Rock Island & Pacific and Lake Shore & Michigan Southern roads, unloading plows were used in at least part of the work. As dry sand in heavy winds is of fugitive character, the Chicago, Milwaukee & St. Paul Ry. has found it advantageous to throw a layer of loam about 12 ins. thick on the slopes of unretained sand filling. Such material on the slope is also less subject to washing down by rains than is sand. The sand filling is topped out with gravel or broken stone, to serve as ballast for the tracks, and during the first year after the tracks have been elevated some attention is required to keep the tracks in fair surface. Tracks elevated 10 ft. on sand filling, on either retained or unretained embankments, will settle about 7 ins. during the first year, when the settlement of the retained embankments practically ceases. On unretained embankments, however, the surface of track does not remain in as good condition as it does on embankments confined within retaining walls, after such settlement.

177. Track Tanks.—The track tank or track "watering trough" is a metal trough usually 6 or 7 ins. deep, 19 to 24 ins. wide and about ½ mile long, placed in the middle of the track. Water is taken into locomotive tenders, at speed, by means of a hinged scoop dropped into the trough by means of a lever manipulated by the fireman or worked by compressed air. Such tanks are used on but comparatively few roads in this country, as the necessity for the same arises only where fast trains must make long runs between stops. For a usual thing only passenger engines are equipped with scoops for taking water from the track, but on the New York division of the New York, New Haven & Hartford R. R., on the Canadian line of the Michigan Central R. R. and on some other roads where it is especially desirable to keep the freight trains moving, the freight engines also take water from the track. The Pennsylvania R. R. and the Lake Shore & Michigan Southern Ry. have a good many freight engines equipped with water scoops.

The trough is usually built of iron or steel plate $^3/_{16}$ in. thick and delivered on the ground in sections, to be riveted together as they are placed in the track. The Chicago, Milwaukee & St. Paul Ry. has two track tanks built of cast iron, in sections 6 ft. long. The track must, of course, be level, and the ties are dapped out $1\frac{1}{2}$ or 2 ins. to make room for the trough (Engraving A, Fig. 516), the top of which is placed even with top of rail. It is not necessary that the track should be straight. At several places on the Pennsylvania R. R. the track tanks are on curves. The top edges of the trough are stiffened by half-round irons and the trough is secured to the ties by ordinary track spikes driven to hook over (as they do the flange of a rail) the horizontal leg of a small angle iron riveted to the side of the trough at the top of the tie. This arrangement permits the trough to expand or contract without disturbing the spikes. The trough is usually anchored to the ties at the middle, and allowed to expand or contract at the ends. At the ends the bottom of the trough slopes upward (Engraving C, Fig. 516), to lift the scoop out of the trough should the fireman fail to raise it at the proper time; and outside the end of the trough there is an inclined plane laid with the intention of protecting the end of the trough from dragging parts of cars, or anything hanging lower than the top of the trough. The incline for lifting the scoop in case of tardy attention on the engine is usually made too abrupt, in this country, and the end of a trough is occasionally torn out by a train running at high speed. A slope 20 ft. long is perhaps none too gradual. It has been recommended that a piece of plank bolted to the end of the trough in lieu of a sloping end would answer every purpose and in case it was torn out it could be quickly and cheaply renewed.

Water is supplied the trough by pumping or from a reservoir, under head. It is usually brought to the trough through a main with branch pipes entering the trough at intervals, so that it may be filled quickly after the water has been scooped out by a locomotive. Where track tanks are used on both the tracks of a double-track road the two troughs are usually interconnected by pipes at frequent intervals, so that the supply of water in both troughs is made quickly available for either track. The usual arrangement for preventing the water from freezing in winter time is to pipe live steam from a boiler plant located near the middle of the trough and admit it into the trough at intervals of 40 or 50 ft. To prevent trouble with pipe connections at points where the trough is permitted to expand or contract with change of temperature, the connection is usually made with a piece of rubber hose, or with some form of expansion joint in the pipe.

On the Baltimore & Ohio R. R., between Philadelphia and Baltimore, the distance of 92 miles is divided into three stretches of approximately 31 miles each, and track tanks (for double track) are placed at the two intermediate points. The troughs of these tanks are each 1200 ft. long, laid on sawed white oak ties 8x9 ins. in section. The inclined planes outside and inside each end of each trough are each 6 ft. 10 ins. long. The trough at one of the points referred to is supplied with water from a 40,000-gal. tank and at the other point from a 30,000-gal. tank, elevated 28 ft. above the track, in both cases. Water enters the trough through three 3½-in. pipes connecting with the bottom of the trough at its middle point and at points 200 ft. from the ends, these 3½-in. inlet pipes connecting with a 6-in. main leading from the pump house, to which the water is brought from the elevated tank through an 8-in. pipe. The valves controlling the admission of water to the trough are placed in the 6-in. pipe at the pump house, and an attendant is on hand at all times to see that the trough is kept full. The time consumed in filling the trough after a locomotive has taken water is from four to six minutes. To prevent the water from freezing in winter live steam is led into the side of the trough at intervals of 45 ft. through 1-in. pipes connecting with a 2-in. pipe running midway between the tracks, which connects with a

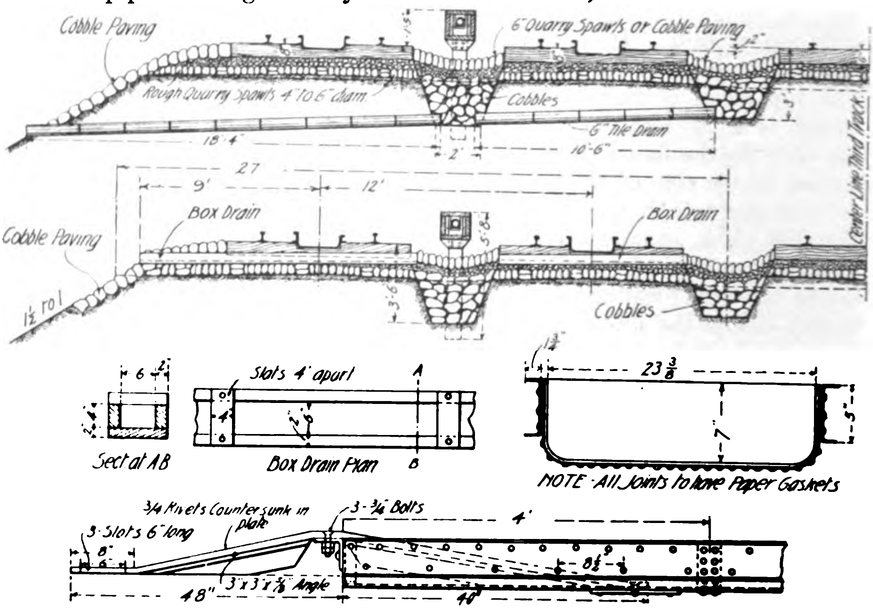


Fig. 517.—Track Tank, New York Central & Hudson River R. R.

2½-in. pipe leading from the steam dome of a large boiler in the pump house. To prevent condensation of the steam the pipes are wrapped and boxed, and 1-in. check valves are used to prevent back flow of water into the steam pipes when the steam is turned off. The connection with the trough is made with a nipple 3 ins. long, tapped and plugged with a stop which has a hole ⅛ in. in diameter inclined downward. The pressure of steam necessary to prevent freezing in the coldest weather is about 80 lbs. per sq. in. Full particulars regarding these tanks, including illustrations and itemized statements of cost of construction and operation, may be found in a paper read before the Association of Railway Superintendents of Bridges and Buildings, in 1892, by Mr. Geo. W. Andrews, supervisor of bridges, buildings and water stations, on the Philadelphia division of the road named.

In the arrangement for operating track tanks on the Baltimore & Ohio R. R. there is, at the end of the trough nearest the approaching train, a signal similar to a high switch stand, to indicate to the fireman when he may lower the scoop, and 100 ft. ahead of the far end of the trough there is a similar signal placed to mark the point where the scoop should be raised. The spout which conveys the water taken up by the scoop is oblong in section and is "goose-necked" into the top of the tender, so that the water enters the tender from above. The scoop is usually 12 or 13 ins. wide, and there is a stop to prevent it from dropping far enough to touch the bottom of the trough. In the scooping position it usually reaches 3 to 5 ins. below the top of the trough. As water may be taken at a speed of 45 miles per hour trains are not usually required to slow down very much in taking water from track tanks. Water has been taken from track tanks by engines running 70 m. p. h.

In a track tank on the Chicago, Milwaukee & St. Paul Ry., at Wadsworth, Ill., about half way between Chicago and Milwaukee, it was found impossible to keep the trough free of ice by the usual method of conducting live steam thereinto, and this experience led to the substitution of a new arrangement, by which the water is heated at the pump house and kept in circulation through the trough. Sectional drawings of this trough are shown in Fig. 516. The trough is 19 ins. wide inside and 7 ins. deep, setting into the ties 2 ins. The joint rivets in the bottom of the trough have countersunk heads. Water enters each end of the trough through a 3-in. pipe, the discharge taking place back of a casting underneath the end slope, whence it flows out into the trough through five semi-circular openings of 1½ ins. radius, through the bottom of the casting, as shown in the sectional drawings *C* and *E*. From both ends of the trough the water flows toward the middle, where there is a 5-in. pipe leading from the bottom of the trough, through which the water is pumped and delivered into an 8-in. pipe at the pump house, into which live steam is admitted from the boiler through a 1-in. pipe. From this 8-in. pipe the 3-in. feed pipes are led to the ends of the trough, as above explained. Thus, after the trough is filled, the water is kept in circulation through the trough and to and from the pump house, where its temperature is raised in the manner described.

Owing to the frequent splashing of water at track tanks the work of maintaining the track in even surface is much more difficult than at points where the conditions are only ordinary. The ballast for the track at track tanks should be broken rock of good depth and the drainage should be well provided for. In very cold weather the constant attention of the trackmen is necessary to keep the flangeways from being obstructed by ice formed by the freezing of the water thrown out by the scoops of the locomotives. The standard track tank of the New York Central & Hudson River R. R. and the arrangement of the drainage is shown in Fig. 517. The top of the roadbed and the top of the ballast are cobble paved, and between the two tracks on which the troughs are laid and between the second and third of the four (main) tracks there are blind ditches 3½ ft. and 3 ft. deep, respectively, filled with 6-in. quarry spawls or cobblestones. At intervals of 100 ft. these ditches are drained from the bottom with 6-in. tile pipe, and every 50 ft. the top surface of the ditch is drained by a 4x6-in. open box made of creosoted 2-in. plank and laid between the ties, as shown. The standard length of the trough is 1400 ft., the width 23⅝ ins. and the depth 7 ins., inside measurements. There are two inlet boxes under the trough, each being 18x12 ins.x2 ft. deep, located 104 ft. apart, near the middle of the trough. The water is fed through a 10-in. main and enters the boxes through 6-in. branches. Each inlet box has a strainer made of No. 14 wire woven to a No. 5 mesh. In the bottom of the trough, near the middle and also near each end, there is a 4-in. washout plug with a 4-in. pipe connection. The steam for heating, in winter, enters the bottom of the trough through $^3/_{16}$-in. brass nozzles 33 ft. apart. The main steam pipe is 3 ins. diam., reduced by sections to 1½ ins. at the ends, and the branches leading to the nozzles are ¾ in. diam. Some of the track tanks of the Lake Shore & Michigan Southern Ry. are 2500 ft. long, being of sufficient length to water two locomotives running as a "double-header." Each engine takes water while running half the length of the trough. Track tanks should not be located near interlockings or at other points where the train is liable to be stopped while taking water.

178. Ash Pits.—At terminal points it is desirable to have sections of track entering roundhouses or lying opposite coaling pockets or water stations built with reference to the convenient removal of ashes and cinders dumped from locomotives. While the construction of ash pits is usually taken in charge by the bridge and buildings department of railways, it is usual to find the clearing of the pits and the loading of the ashes in charge of the section men, and unless the arrangement for such work be planned with a view to convenience too much time will be spent on the accumulated ash heaps. From the trackman's standpoint it is, therefore, pertinent to consider the various types of ash pits, with the

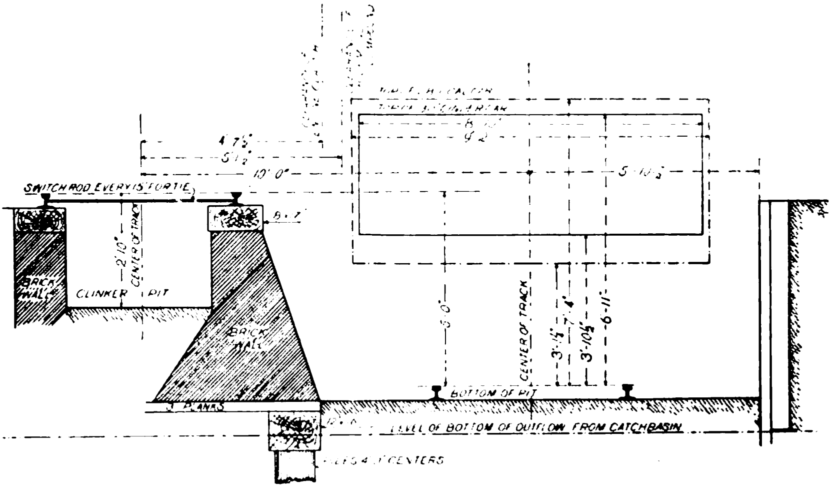


Fig. 518.—Ash Pit and Depressed Track, C., B. & Q. Ry.

attending facilities for clearing away and loading the ashes, if not the details of construction. It is too frequently the case that the ashes from a considerable number of locomotives are dumped upon the ties, to be shoveled out of the track daily by one or more men detailed from the section crew. While such an arrangement may be satisfactory at water tanks on main line, where high speed is made, the scheme is not an economical one for side-tracks or yard tracks where a number of locomotives are taken care of, for the ash heaps rapidly accumulate close to the track until the hostlers are discommoded in their work, for lack of room; and at last it becomes necessary to clear away the obstruction in some way, and it is frequently done by throwing part of the heap farther back. In any case the ashes have to be handled at least twice by the time they are loaded upon the cars, and where heaps are permitted to accumulate it sometimes happens that they are rehandled several times before they are finally loaded and hauled away.

To facilitate the removal of the contents of the ash pans a pit is sometimes constructed in the track, from which the ashes are shoveled out into heaps and afterwards loaded onto cars standing upon a parallel track, or run to place over the pit; but, so far as the cost of handling the ashes is concerned, such an arrangement is but little if any better than that of dumping the ashes upon the ties. The only improvement at all worthy of consideration is some arrangement whereby the ashes may be loaded onto the cars at the first handling; and if they must be loaded by hand, the only satisfactory arrangement is a depressed loading track, on which cars may be kept standing to receive the ashes as they are thrown out of the track or pit. An elevated dumping track, of course, corresponds to the same arrangement. It will be understood that the term ashes, as used in connection with the present subject, is intended to include cinders and clinkers as well.

The ash pit most commonly found in this country is a pit in the track, about 4 ft. wide and 3 or 3½ ft. deep, enclosed on both sides, with a depressed parallel track about 3 ft lower than the bottom of the pit, at convenient distance for loading the cars. Such pits are walled up with stone or brick laid upon a suitable masonry or concrete foundation and coped with stone, timber stringers, or wrought or cast iron plates. Ordinary hard-burned brick is the material most commonly used for paving, being set on edge, either in concrete or in a bed of sand, and sloped longitudinally and transversely for drainage, which is usually effected by means of 4 or 6-in. sewer pipe, with catch basins. Fire brick are sometimes used for paving the bottom of the pit and facing the side walls, but they are too soft to withstand the pressure from the weight above and the wear from the workmen shoveling in the pit, and hence ordinary hard-burned brick or ordinary brick faced with paving brick, are preferred. For the bottom, paving brick grouted with cement are used a good deal. It is also very commonly the practice to protect the bottom and sides of the pit from the heat of the cinders by a lining of old boiler plate, or cast iron plates about 1 in. thick, leaving an air space of about an inch between the plate and the wall. Where timber stringers are used for coping they are usually anchored by bolts passing down into the masonry, and the rails are spiked to them with ordinary spikes having the point turned 90 deg., so as to cut crosswise the grain of the timber. To protect the coping timber from fire the Chicago, Burlington & Quincy Ry. uses a sheet iron cover placed as shown in Fig. 490A. The material for these covers is obtained by cutting up old tank iron and bending it to such shape that when anchored against the timber there will be a 1-in. air space all around. To maintain this air space old nuts are placed between the wood and iron, at intervals, through which are run the lag screws securing the plate. The air space is closed in by bending down the edges of the iron plate, top and bottom, thus preventing cinders from filling up the opening. Where an iron or steel or cast iron plate is used for a coping the rail is riveted to the plate or fastened to it with bolts and clips and the plate is secured to the masonry by anchor bolts. In some cases, however, the rail rests directly upon the masonry and the fastenings consist of anchor bolts and clips or ordinary track spikes driven into wooden plugs about 2 ins. in diam., which are set in holes drilled in the masonry.

At a pit of this kind it is, of course, necessary to run the locomotive off the pit before the ashes can be shoveled out, and in case locomotives follow in rapid succession a small pit of the kind is liable to become clogged before the shovelers can get into it. While, as above stated, pits of this type are more numerous than any other, the design does not meet with as much favor for new construction as it formerly did. Figure 518 is typical of this style of pit construction. For convenience of loading the cars the pit and loading tracks are laid at only 10 ft. centers. The cost of loading cinders at a certain pit of this kind has averaged 97 cents per car-load of 27 cu. yds. (heaped). Before the depressed track was used the cinders were first shoveled from the pit to a platform, and from this platform into the car, at an average cost of $1.77 per car-load, same capacity as stated above. This comparison shows the economy of loading direct from pit to car.

A style of pit which meets with a great deal of favor is one that is open on the side toward the depressed loading track, as then the ashes may be raked out of the pit and loaded into the cars without hindrance from locomotives standing over the pit. It is desirable to have a clear space or platform 5 or 6 ft. wide between the open side of the pit and the side of the ash car, or a spacing of 14 or 15 ft. between the centers of pit track and loading track; and, to aid the shoveler, the bottom of the pit and floor of the platform should be sloped toward the loading track. The rail on the open side of the pit is usually supported upon cast iron pedestals or columns, or cast iron piling, and the rail on the closed side by the same means or by a wall with suitable coping and fastenings for

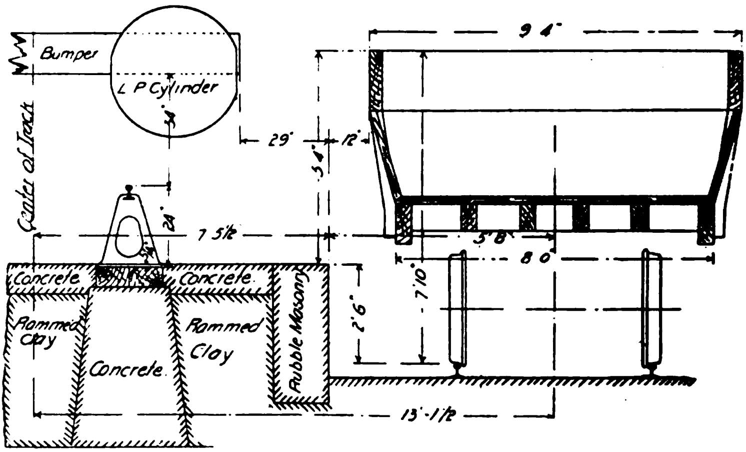


Fig. 519.—Ash Pit and Depressed Track, Northern Pacific Ry.

the rail. The pedestals are usually supported upon a longitudinal masonry pier, or upon the concrete bed on which is laid the paving of the bottom of the pit. Where the span between the pedestals is more than 3 ft., but does not exceed 6 ft., the running rail is usually reinforced for support by riveting it to an inverted rail fitting a suitable bearing or seat in the casting; but where the span exceeds 6 or 7 ft. the immediate support for the running rail is usually an I-beam, varying in depth according to the span. It is frequently selected from scrap bridge material. The rails are usually held to gage with switch rods or with long bolts through pipe struts. In order to cause the ashes to slide out upon the loading platform as they are dumped from the locomotive, inclined plates are sometimes placed against the back side of the pit or the bottom of the pit is laid to a slope. The edge of the loading platform is sometimes curbed with a line of old rails.

Figure 519 is typical of the foregoing style of ash pit. The track over the dumping pit is carried on cast iron pedestals 24 ins. high. The distance from the center of this track to the center of the depressed track is 13 ft. 1½ ins. The top of the car into which the cinders are loaded is

5 ft. 4 ins. above the level of the clinker pit. The difference of level between the loading platform and the depressed track is not as much as it ought to be to make the loading of the cinders easy. An ash pit of similar construction on the New York Central & Hudson River R. R. has six lines of old rails embedded in the concrete under each row of pedestals. To prevent the concrete floor from being cracked or broken up by the hot ashes, there is a galvanized netting of No. 8 wire, 1x2 ins. mesh, embedded in the concrete near the top surface.

It is obvious that the deeper the depression for the loading track the better is the work of loading the ashes facilitated. At East Tyrone, Pa., on the Pennsylvania R. R., there is an ash pit 120 ft. long and 3½ ft. deep, with a loading track depressed 8 ft. below the floor of the ash pit, the two tracks being 11 ft. 7 ins. centers The top of the masonry retaining wall for the pit of the loading track is corbeled out on a level with the top of a gondola car, and the ashes are loaded by raking them out of the pit and shoving them directly into the car. The floor of the pit, which is paved with hard red brick set in cement, slopes toward the car. In cleaning 131 freight engines and 21 passenger engines at this pit, daily, it was found that on an average 1¼ cu. yds. of ashes were handled per engine. At San Luis Obispo, Cal., on the Southern Pacific road, there is a pit of this type 3 ft. deep with the loading track depressed 9 ft. below the ash-pit floor, and the loading and pit tracks are located 9½ ft. centers. The rail on the open side of the pit is supported every 3 ft. upon cast iron pedestals, and in each span there is suspended across the pit an iron chute 3 ft. wide, under the pit, 5 ins. high and about 10 ft. long, extending out over the ash car. The width of the chute between the pedestals and outside of them is 2 ft. 5½ ins. and the chute is set at a slope of 1 in 9. Six of these chutes are placed closely side by side, making a solid length of 18 ft. under the pit. The ashes are dumped from the locomotive into these chutes and washed down into the car by water from a spray pipe under a pressure of about 80 lbs. per sq. in. It is said that the arrangement requires but little water and works successfully.

Another very common type of ash pit, and one which requires no special drainage, is formed by raising the track above the general level of the ground, supporting the rails upon low iron pedestals or chairs, the spaces between which are left open on both sides of the track. At some pits of this kind the ashes are shoveled and loaded into cars standing on parallel tracks at the ground level, but the most commendable arrangement is to depress the loading track, as in the cases aforementioned. Cast iron pedestals for such pits are made from 12 to 24 ins. high, and a common form or arrangement for the foundation is to stand the pedestals upon longitudinal stringers supported upon cross ties, or upon cross ties supported upon longitudinal stringers, the woodwork being protected from the live coals by a covering of earth, gravel, concrete, or by a brick paving. The pairs of pedestals may be tied across the track at their bottoms by riveting to channels or by bolts and web pieces, or by bolting to old rails, but the more usual arrangement is to cast the two pedestals and the tie between them all in one piece. In pits of this kind on the Union Pacific and Southern Pacific roads the pedestals are formed of old rails bent to form an "L" for each side of the track, each pair being tied together across the track by a piece of rail bent into a U-shape. These pedestals are set 6 ft. apart and the running rails are supported directly upon an inverted rail resting upon the vertical leg of the U-shape. Where the running rail at a pit of this kind must be assisted in its support by another rail or by an I-beam underneath, some headroom is lost, thereby obstructing to some extent the work of drawing the ashes out of the pit sidewise. An arrangement which practically obviates this objectionable feature is in service on the Atchison, Topeka & Santa Fe Ry., where two 7-in. I-beams are used for the support of each rail, over cast iron pedestals spaced at 9 ft. centers In this case the I-beams are separated about 6 ins. and the rail is supported upon blocks placed between the beams and bearing upon their lower flanges, the top of the rail coming flush with the tops of the I-beams.

By carrying the chair-supported type of pit (above ground line) a little farther another type of pit is recognized, whereby the track is elevated on an iron trestle, open on both sides, underneath, the ashes being dumped on the ground and shoveled up and loaded at convenient times onto cars standing on parallel tracks. The purpose of this arrangement is, of course, to afford storage space for the ashes and to obviate the necessity of having to attend closely to the removal of the ashes. A pit of this kind is in service on the Central R. R. of New Jersey, at Jersey City, N. J. The track is elevated 7 ft. above ground level, on trestle bents at 15-ft. spans, the rail being carried on girders, each of which is formed by two 15-in. I-beams weighing 150 lbs. per yd. On each side of the

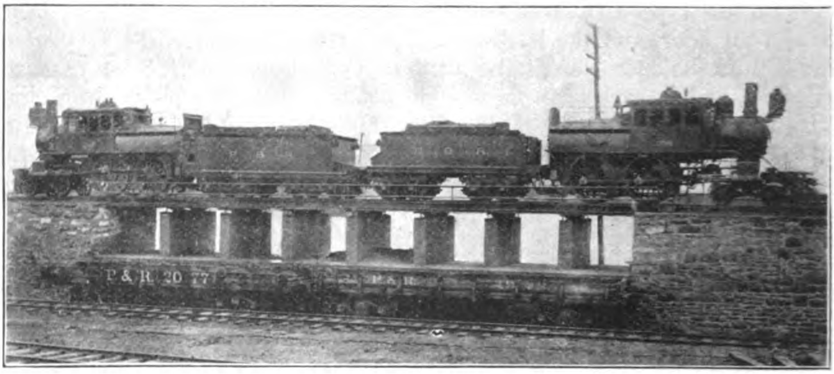


Fig. 520.—Ash Dump, Philadelphia & Reading Ry.

track there is a plank walk supported upon brackets extending from the girders. The loading tracks are located each side of the trestle, the center of each track being 16 ft. from the center of the trestle. This trestle is 225 ft. long, with filled approaches on 5-per cent grades at each end. The loading tracks are at the ground level.

Figure 520 shows this style of ash dump carried one step farther, providing a depressed loading track for the elevated dumping track. This dump is at Reading, Pa., on the Philadelphia & Reading Ry. The pits into which the ashes are dumped from the locomotives are arranged under a track elevated to such a hight that 6 ft. of clear headroom remains between the floor of the pit and the under side of the girders supporting the rails, while the floor of the pit is on a level with the top of a gondola car standing upon the loading track, at the side of the dump. The retaining wall for the elevated track is 444 ft. long, of rubble masonry laid in cement mortar. The dump is approached at each end with grades of 5 per cent, eased by vertical curves at the points where the grade changes. The top of the rail over the dump is 8 ft. above top of rail on main tracks, while the loading track is depressed to bring the top of rail 5½ ft. below top of rail for main track. The dump is 72 ft. in length, divided into eight pits, each 9 ft. in length between centers of partition piers. Each track rail rests directly upon the top flange of a 12-in., 170-lb. I-beam, in lengths of 17 ft. 11½ ins., or long enough to extend over two panels and leave ½ in. for expansion at the joints. At the panel points the I-beam girders are connected across by a 9-in. I-beam, and the joints are spliced by a cast iron plate inside the girder, and a wrought iron plate outside the girder, tied together by long bolts reaching across both girders. The I-beam girders at the panel points rest upon an inverted channel weighing 100 lbs. per yd., filled with cast iron blocking and supported upon a bent composed of four Phoenix columns, which form the actual support for the track. These columns are bricked in to form piers, but the brickwork has no office to perform other than to protect the iron columns from the heat and the action of the sulphur in the ashes, and to afford transverse support for the bent. The top of the brick pier is coped with cast iron and the columns are filled and rammed with concrete. The columns, caps and bases were of old material, in stock, and were used to enable the construction of narrow piers, thus saving room. On each side of the track there is a concrete walk 3½ ft. wide, formed upon three T-rails laid longitudinally and cross connected with bolts trussed to support the concrete. The length of each brick pier is 12 ft., crosswise the pit, and the floor of the pit is 20 ft. wide, or 10 ft. each way from center, sloping from center toward either side. The pit and loading tracks are 15½ ft. centers. The floor of the pit is laid with brick set on edge in Portland cement mortar, floated with grout as laid. The edge of the pit floor next the loading track is curbed with a T-rail laid on side with the base against an upturned bead on the L-shaped coping of the side wall. The brick used in this work is low in silica and burned very hard.

With a view to cheapen the cost of loading ashes where large quantities have to be handled, as at roundhouses, power machinery has been quite extensively applied. One system that is in service on a number of roads, with evident satisfaction, consists of an ordinary depressed, closed pit with ash buckets lifted out and in with a crane. One style of arrangement has buckets about 8 ft. long, 3 ins. narrower than the pit, and holding about 3 cu. yds or about 5000 lbs. of wet ashes. The bucket is made of old tank iron, and the top part fits the pit so closely that practically all of the ashes dumped from the locomotive fall into the bucket. The post of the crane is usually located about 9½ ft. from the center of the pit and the crane can be swung to handle two buckets. In order to obviate the necessity of multiplying cranes at a long pit it is the practice in some cases to set the ash buckets upon wheels, which run upon a narrow-gage track in the pit, on which the buckets can be pushed to a point within reach of the crane. In some cases the crane is operated by a hand winch, but there are various ways of securing power for working the crane, one of which is to utilize the locomotive which has been cleaned, to hoist the bucket as it leaves the pit. A chain is attached to the locomotive when it is ready to leave and the bucket is hoisted, when the locomotive is released. The crane and suspended bucket are then swung around to bring the bucket over a loading car upon a parallel track and the ashes are dumped by tripping the hinged bottom of the bucket. In a number of instances the hoisting and the turning of the crane are worked by compressed air piped from the shops or obtained by a connection with the air-brake apparatus of the locomotive. In handling and loading ashes by this method no force is needed besides the hostlers, or the men who clean the fire-boxes. According to figures reported officially from the Baltimore & Ohio Southwestern R. R. the cost of handling ashes with buckets and cranes, as ascertained by trial on that road, was only one third the cost of handling the same by shoveling from a depressed pit. On this road the cranes have been worked by both systems of power —locomotive and cable, and compressed air. One of the plants operated by air (at Chillicothe, O.) is illustrated in Fig. 521. The hoisting is done by means of a 12-in. cylinder with a 14-ft. stroke and the crane is turned by a double-acting cylinder 8 ins. in diam., with a stroke of 4½ ft The hoisting cylinder is anchored to the ground in a horizontal position, and power is applied to the crane by attaching the hoisting chain to a hook on the end of the piston rod. This cylinder is also used to pull the cars into position for loading as the work of filling them progresses. The air pressure is 65 lbs. per sq. in.

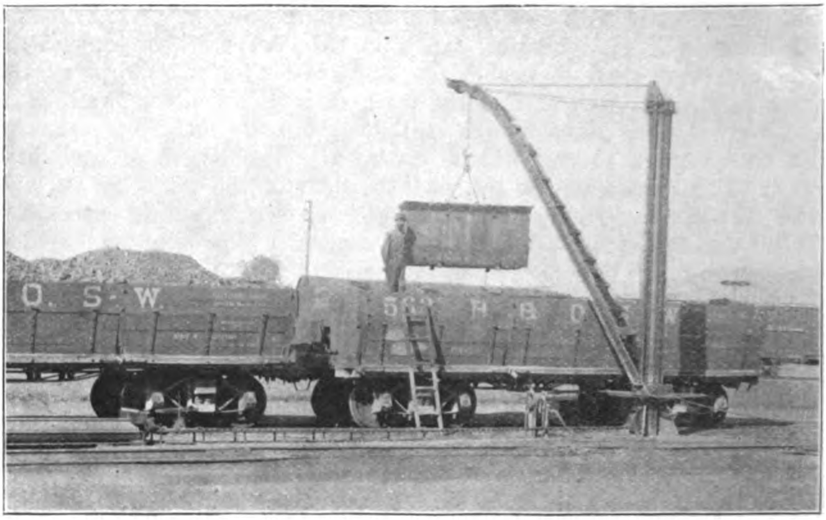


Fig. 521.—Ash-Handling Crane and Bucket, B. & O. S. W. R. R.

For lifting cinder buckets in its yards in St. Louis the Missouri Pacific Ry. uses a portable crane mounted upon a truck or small flat car. The crane is operated by air from a storage reservoir on the car. Instead of using a pit as a means for placing the buckets under the locomotives, the dumping track is elevated 2½ ft. above the ground and supported on cast iron pedestals 7 ft. apart, on which are placed two lines of inverted rails to serve as stringers for the support of the track rails. The buckets are of cast iron 18 ins. deep, and are suspended by means of flanges at each end which rest upon the tie rods between the track rails. There is a series of buckets suspended one after another to cover the length of the dumping track, and the portable crane is run upon this track, lifting the buckets one at a time and swinging them into position for dumping into cars on a parallel track. The time required to lift and dump the 27 buckets at one of the roundhouses is 40 minutes. The Robertson cinder conveyor, in use on the Grand Trunk Western Ry., at Elsdon, Ill., consists of an iron car running upon an incline track which enters the ash pit at the side. This incline track extends laterally over a depressed track which is parallel with the pit and 18 ft. distant, center to center. The ash car is hauled up the incline by a cable and compressed air cylinder, and as it arrives over the depressed track its bottom is automatically tripped and the ashes drop into a gondola or other car spotted under the incline for loading.

Ash pits should be located on a double-ended piece of track, or a siding which has an outlet at both ends, so that after an engine has been cleaned it may pull straight ahead off the pit and not be prevented from leaving by some engine which has come in behind it. The depressed loading track usually descends into its pit on a steep grade and it usually has a dead end. It is not infrequently the case that two short pits are used instead of a long one, and in such event the depressed loading track is run between the two ash pits. At any style of ash pit water should be available, with hose connections for wetting down the ashes, so as to relieve the walls of heat and enable the speedy removal of the ashes from the pit.

Ash pits should not be put in main track outside of yard limits or wherever trains run at full speed. In such places they are equivalent to pit cattle guards as an ever-present menace to trains running with a derailed truck. The standard main-line ash pit of the New York Central & Hudson River R. R. is 5½ ins. deep from base of rail The foundation is a bed of cinder concrete 12 ins. deep and 8 ft. wide, on which are placed 12x12-in. longitudinal creosoted yellow pine sleepers to support the rails. These sleepers are tied together at intervals of 3 ft. with ¾-in. rods, and to protect them from fire the top corners inside the rails are covered with angle irons. Between the sleepers the concrete bed is 18½ ins. deep, extending as high as the middle line of the stringers, to cover the tie rods. The bottom of the pit is faced with a 1½-in. layer of cement mortar. For further information on ash pits of a large variety of designs, regarding full details of construction, cost, economy of operation etc., the reader is referred to a lengthy committee report to the Association of Railway Superintendents of Bridges and Buildings, in 1894. The subject is also treated quite fully in Berg's "Buildings and Structures of American Railroads."

Wherever ashes and cinders are frequently dumped on the ties, as at stations, water tanks or in side-tracks, it is best, when cleaning up the track, to leave a layer about 1½ ins. deep to protect the ties from being burned the next time hot ashes are dumped. Where considerable quantities of ashes have to be cleared away daily it is well to keep coal scoops at hand for this purpose, as it is slow work handling such material with track shovels. At water tanks on busy roads, where ash heaps in the track should be cleared away promptly, a hose should be arranged for cooling off hot ashes.

Conveyor Plants.—The most modern arrangement for handling large quantities of locomotive ashes and cinders is a conveyor plant, which takes the ashes from the bottom of the pit and deposits them in an elevated hopper-bottom bin placed over a loading track, from which they can be discharged into cars by gravity. Such facilities are frequently combined with a coaling station plant, to be operated during intervals when coal is not being elevated. There is usually a hopper-shaped pit, under which there is a spiral or a bucket-and-chain conveyor carrying the ashes to an elevator line which delivers them into the elevated bins or pockets. An example of such a plant is illustrated in Fig. 522. There is an ash pit 70 ft. long on each side of the house and an elevated bin over each of the two loading tracks inside the house. There is also a sand bin on each side of the house. The pits are solidly constructed with concrete walls 8½ ft. deep and 8 ft. wide, out to out. The walls, which are 3 ft. thick at the bottom of the pit, taper to a thickness of 12 ins. at the top. The pit is 4 ft. wide at the top, 2 ft. wide at the bottom and 3 ft. deep to the top of the conveyor. To protect the corners of the concrete walls from being chipped off by bars and scrapers thrown against them they are faced with steel plates which hang down 16 ins. from the top. A view looking into one of these pits is shown in Fig. 509A. In the bottom of the pit there is a cast iron grating, to prevent clinkers of too large size from getting into the conveyor, and the grating is covered with steel plates provided with rings for convenient handling. The cinders drawn from the fire boxes fall on these plates and are quenched, and when the pit is full the plates are successively removed, allowing the cinders to fall into the conveyor below. Full details and illustrations of the

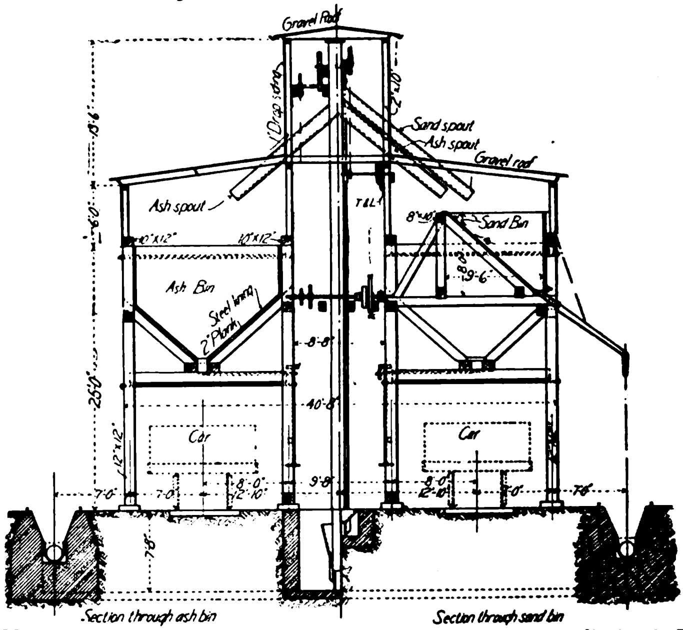


Fig. 522.—Cross Section of Ash and Sand-Handling House, Ill. Cent. R. R.

construction and operation of typical modern ash-handling plants were published in the Railway and Engineering Review for July 29, 1899, and March 15, 1902.

179. Track in Tunnels.—The roadbed in tunnels is usually a rock surface, dressed off to give proper drainage, or an invert of brick or concrete masonry arched downwards to prevent the bulging of the bottom of the tunnel, in case soft or yielding material is encountered. For the track the usual construction of cross ties and ballast is the rule in this country. In Europe longitudinal wooden stringers are used to some extent as supports for the rails, without ballast, the stringers being laid directly upon the masonry of the invert or upon a bed of concrete. Engineers who favor the stringer construction contend that the maintenance work is much facilitated, particularly in renewals; that the drainage can be better provided for and better inspected; and that where ballast is dispensed with there is a considerable saving in hight of tunnel, which effects a saving in excavation, and also in masonry construction if side walls have to be built.

Drainage of track in tunnels is usually provided for by a blind drain of box form built of stone and overlaid with flagstones, placed underneath the track, where there is but one track over a masonry invert, or in the bottom of the tunnel midway between the two tracks, in case of double track. In other cases there are narrow open ditches next the side walls of the tunnel, with curbstones to retain the ballast, or lines of stoneware pipe are laid and covered with ballast, so that the floor is available its entire width. Where springs or large quantities of water are encountered it is customary to lay drain pipe behind the side walls. The necessary fall for drainage purposes is usually provided for by running the tunnel to a summit at the middle or by a grade the whole length. The St. Clair tunnel, on the Grand Trunk Ry., is circular in section and lined with flanged cast iron plates or sections bolted together. In this tunnel the ties are supported upon four 6x12-in. longitudinal sleepers laid directly upon a concrete bed. Guard timbers are bolted to the ties, outside the rails, as on a bridge floor, and a drain 18 ins. wide is formed in the concrete bed, between the two middle timbers supporting the track.

The best ballast for track in wet tunnels is broken stone, as it forms less obstruction to the drainage than other kinds. In dry tunnels gravel ballast does very well. In tunnels through shale rock the disintegration of the shale on exposure to air and moisture is sometimes a source of considerable trouble in the way of maintaining the ballast. On a wet bottom of this kind, especially where water has come through the roof, it has happened that the disintegrated material of the floor would work up through the ballast in the form of clay and mud. The remedy applied in such cases has usually been to remove the softened rock and replace it with a layer of concrete.

As a rule the metal parts of track in tunnels deteriorate rapidly from corrosion, at any rate much more rapidly than with track in the open. This is due to the corrosive action of smoke and gases from locomotives, and in many cases also to dampness. The severity of these conditions depends, of course, a great deal upon the length of the tunnel, which has to do with the ventilation, and upon the amount of water dripping from above. The loss of metal to rails takes place all around the section. In some cases rails in tunnels have lasted only half to a third as long as rails under the same traffic conditions out in the open; and some writers have speculated on the rate of corrosion, but owing to the varying conditions of ventilation, dampness, nature of the fuel burned by the locomotives, the frequency of the train movements and the length of the tunnel it is not possible to deduce useful rules from the data presented. Owing to the fact that the ballast takes in a good deal of smoke and gas and becomes mixed with cinders it is desirable to dress it off clear from contact with the rails, so that the latter may get full benefit of whatever ventilation there is. In wet tunnels, where there is usually a bad rail, a good deal of sand must be used, and this causes excessive wear from the top. To protect rails in tunnels from rusting some of the English railways, including the Midland and the London & Northwestern roads, paint them with four coats of red lead before they are put into the track. A paper on "The Wear of Steel Rails in Tunnels," written by Mr. Thomas Andrews and presented at a meeting of the Institution of Civil Engineers, on April 10, 1900, treats of the subject somewhat thoroughly from the standpoint of English railways. In one tunnel 3000 ft. long the average loss in weight of rails from corrosion and wear was 2.8 lbs. per yard per annum, as compared with an average annual rate of 0.324 lb. per yard for rails under the same volume of traffic in the open air.

The life of ties in tunnels is also another important matter for consideration. As tie renewing in tunnels is much more expensive than in open space, the ties for such places should be selected with a view to obtain the longest life possible. Undoubtedly the best plan is to use creosoted ties of best quality. In damp tunnels the moistened ties are rapidly cut under the rails, and where sand is frequently used this action is much augmented. The use of tie plates improves the situation, but by corrosion and the grinding action of the sand they do not last as long as on open track, and are therefore more expensive than ordinarily. In long or damp tunnels steel ties rust out rapidly and are not found to be satisfactory. On the St. Gothard Ry., in Switzerland, where 70 per cent of the track is laid with metal supports, wooden ties are used in the long tunnels. Metal ties have been tried there but in every instance their life was short.

Owing to the restricted space and to darkness, track work in tunnels is necessarily more difficult of performance and more expensive than is ordinarily the case with track on the outside. In renewing ties in single-track tunnels of ordinary width (15 ft.) there are several ways to get the old ties out and the new ones in. The easiest method is to draw the spikes on one of the rails and lift it up and block it or throw it laterally off the ties. Sometimes this is done with both rails, as then some digging may be saved, but it is not necessary to take the rails up; that is, to uncouple them at the joints. When the work is done in this way it is necessary, of course, to send out flagmen, but if the frequency of the traffic will not admit of this the ties have to be handled without disturbing the rails. By digging a downwardly slanting trench the old tie may be pulled to one side, one end lifted and the tie pulled out between the rails, and the new tie may be put in by the reverse process. Another way to get the old tie out is to dig a trench and cut the tie in two, when it may be taken out between the rails, in separate pieces. Another way to get ties out without digging deeply into the ballast is to remove the filling from between them, bunch four or five together and then slew the bad one at an angle of about 45 deg. and lift it out between the rails. New ties may be put in by reversing the process. This plan of renewing ties in tunnels is followed quite extensively. If there are no obstructions at the ends of the ties they may be taken out or in by slewing them outside the rails. Two ties are handled together. The ballast is removed from three spaces between ties and then one of the ties is pulled to one side of the track and slewed out under the rail and the other tie is pulled over and slewed out under the opposite rail. Both ties may, however, be slewed out under the same rail, by first pulling one of them back in the opposite direction far enough to make room to slew the first tie taken out; or only one of the ties need be taken out, the other being simply slewed to let the bad tie out and the new one in. For reasons presently explained trackmen are not usually permitted to lift track bodily when renewing ties in tunnels. In single-track tunnels it usually pays to renew ties out of face, as often as conditions may require. On this plan it is necessary to engage in the work only once in a period of years, which is more economical of labor than that of renewing part of the ties under difficulties each year. On roads where the renewing is done out of face the ties taken out that will see further service are used in side-tracks.

The work of track maintenance in single-track tunnels is also impeded by the necessity for the men to run to cover when trains approach. Alcoves, niches or manholes, as they are variously called, are usually built in tunnels at suitable intervals for workmen to secure a place of refuge from passing trains. In the Boulder tunnel, on the Montana

Central branch of the Great Northern Ry., which is 6112 ft. long, an arched hand-car recess 7 ft. wide is built into the side wall in two places, each 2000 ft. from either end of the tunnel, so that a hand car in passing through the tunnel is at no place farther than 1000 ft. from a place of safety. Trackmen should not enter dark tunnels without lights to signal trains, and when engaged in such places they must have lights to work by. Where only slight repairs have to be done trackmen can get along with hand torches, but where extensive work is going on it pays to have large pot torches, or lights of the Wells or Buckeye kind. The latter are used a great deal. When lining track in dark tunnels a torch or lantern may be held over the rail to give light, but when track is being surfaced it is desirable to have the tunnel lighted up so that 150 to 200 ft. of rail may be seen distinctly. It takes a good many hand torches to do this.

Methods of track work in tunnels apply in a general way to snow sheds, except that torches or other artificial lights are not usually needed, although in winter the working days are shortened an hour or two. The ventilation openings or screens that are sometimes left in the side of the shed, near the top, let in a good deal of light, and more or less light comes in through cracks between the planks on the roof and sides. For lining track in snow sheds a dull day is selected, as in bright weather the sun shining through the cracks strikes the track in streaks and patches and bothers the man sighting the rail. In snow sheds and at the ends of wet tunnels it is important to keep close watch of ice that may freeze and obstruct the ditches or accumulate around the rails from water dripping from above. Whenever such danger is threatening a watchman should be detailed to visit the place at proper intervals to keep the ditches open and pick or chop the ice clear from the rails.

Clearance.—In lining or surfacing track in tunnels and snow sheds it is important for trackmen to observe the established clearances. In such places the general surface of track cannot be raised without reducing the vertical clearance, and as this is of record in the office of the engineering department, such changes should never be made without permission or orders from that department. The rules of the road department of most railways forbid trackmen to raise the general surface of track in tunnels, or under overhead structures that come anywhere near the established clearing distances. This rule, of course, permits raising low joints and other low places in the track, but not higher than is necessary to bring the rail to an even surface on the existing grade. For measuring clearance in tunnels and snow sheds, at bridge openings and at side structures that are close to the track some roads use a special flat car carrying a templet or framework built approximately to the outlines of the supposed clearance. This is arranged transversely on the car, with a platform high enough to enable the inspectors to use foot rules or measuring sticks to take the clearance, measuring from the templet as a reference.

The clearance-measuring car of the Pennsylvania R. R. is a specially constructed long flat car with a platform about 9 ft. square erected over one of the trucks and standing about 5 ft. above the floor of the car. Railed stairways lead to the platform on two sides, and there are substantial railings around the platform and all around the car. Each end of the car is equipped with a platform and steps of the passenger-coach pattern. The templet from which the measurements are taken was built approximately to the outlines of the existing minimum clearance records, and stands 15 ft. high above the rail, being graduated every 3 ins. The vertical leg of this templet, on either side of the car, extends as low as the ordinary car step, and is hinged so as to trail with the car in case it should meet with an obstruction. To provide against meeting with an unexpected obstruction overhead, the arched part of the templet is also hinged to fall backward in case it should strike anything. To prevent any possibility of passing an obstruction within the required clearance without observation, as might happen in a tunnel or after dark when the vision is obscured by smoke or steam, the perimeter is set with wooden pegs about 3 ins. apart and projecting 6 ins. from the edge of the templet. Should any of these pegs be broken off while the car is in inspection service it is then known that some obstruction has been passed which requires investigation. Coupled in behind this car in the clearance-measuring train there is a dining and sleeping car for the crew, and there are storage batteries to supply current to electric lights of high candle power on the platform of the clearance-measuring car, for use when taking measurements in tunnels, or when work is continued into the evening in order to reach some desirable point for lying over night. The measurements taken at any point are recorded on a printed diagram of the templet, and obstructions met with are sketched thereon. This car is used whenever new lines, tunnel or through bridge work are completed. Between times the car is dismantled, the templet and platforms being stored in the shops and the car put into ordinary service.

To get measurements of the cross section of a tunnel with reference to the track it is necessary to erect the templet frame over the center of one of the trucks, but sharp curves sometimes occur in tunnels and quite frequently in snow sheds, and in such places record should be taken of the clearance at the middle of long cars, as affected by the overhang. For this purpose there might be an additional templet at the middle of the clearance-measuring car; and the length of the car and the position of the trucks should correspond to similar measurements of the longest sleeping car or other car of maximum length liable to be hauled over the road.

In a paper on "Maintenance of Railway Tunnels," by Mr. Arthur Watson, read before the Institution of Civil Engineers (extracts were printed in the Railway and Engineering Review, Apr. 13, 1901), that author calls attention to an instrument for measuring the contour of a tunnel cross section, that is designed on the pantagraph principle. There is a bar or piece that is placed across the rails of the track, or across the two inside rails of a double track, to center with the center line of the track or tracks, and on this there is a fixed drawing board 27 ins. square standing vertically. Attached to this drawing board on its vertical center line there is a telescopic shaft or pointer of light construction, carrying a small wheel at the end which is passed around the soffit of the tunnel arch and side walls. This shaft or pointer is attached to an arrangement of crossed bars of the familiar proportional divider style. At a fixed place on the drawing board there is a piece of drawing paper which shows, in firm lines, the minimum clearance profile. Attached to the pantagraph bars (at the first crossing point) there is a pencil held to proper contact with the paper by a spring. When the cross section of a tunnel is to be taken at some point a sheet of tracing paper is pinned to the face of the board, over the drawing paper and diagram referred to, and on it are traced the rail level and vertical center line of the tunnel section. By traversing the telescopic pointer around the soffit or roof and sides of the tunnel a correct contour of the same is produced on the tracing paper, one twelfth full size. Having the minimum clearance profile already drawn the comparison is graphically shown, and the clearances can be readily scaled off the drawing.

The general purpose in taking car clearances is obvious, but one specific purpose is to collect data to govern the issuing of special permits for the transportation of merchandise freight carried on flat cars, but which may be a few inches wider than the cars or slightly higher than the general standard. The minimum clearance on each division or between certain points of a division is usually represented by a diagram, and the various diagrams for a road are of record in the general offices of the engineering and transportation departments.

180. Resurveys.—Many of the railroads of this country were hurriedly constructed, without careful surveys or the filing of proper records. As a consequence irregularities in track alignment and surface become more and more noticeable, with time, no reference points being available, so that the re-establishment of center and grade lines becomes a necessity, if the track is to be maintained in good condition. It is also to be considered that the attention of maintenance of way engineers is being more and more directed to the relocation, in part, of many of the old lines, to secure more favorable grades and curvature, thereby making it possible to increase the tonnage of trains, or to equalize the tonnage over all points of the same division of the road, and to increase the speed of the trains. In connection with work of this character good opportunity is found for the establishment of the surveys throughout on a more accurate and enduring plan. One of the principal objects is, of course, to establish points of curvature, which should then be permanently marked with substantial monuments, which are treated in § 48. It is quite common experience that changes are made which shorten or lengthen the line, as the case may be, after the permanent location has been run, and resort is had to equated stations, in order that each change so made need not affect the station numbers of the entire line beyond. Such changes also occur in the relocation of a line for the reduction or elimination of curvature. In the resurvey of a railway such equations should be taken out and the line measured continuously from the starting point, changing the positions of the mile posts as occasion may require. Such was done in the resurveys of the Detroit, Grand Rapids & Western and the Chicago & West Michigan roads, and a piece of old rail 5 ft. long was set 30 ft. to the left of each mile point, the base facing the track, with the number of miles stamped thereon.

The resurvey of a railway should be thoroughly carried out, taking note of all matters pertaining to the roadbed and right of way which are liable to become of use to the company's officials. While it will not be necessary here to go into the details of surveying it should be said that all the physical features of any consequence on the right of way and for some little distance off the right of way, should be located and platted on right-of-way maps, or made matters of record by descriptive data of some sort. Thus it is important to accurately locate all fence lines and the boundaries between lands of separate owners adjoining the right of way, as well as state, county, township and town boundaries, and section lines of government surveys. In work of this character it is also customary to locate all buildings within 200 ft., on each side of the center line, and in towns and cities all property is sometimes mapped as far out as 400 ft. each side of the line. Accurate data should be obtained regarding the important features and measurements of bridges and culverts along the road, and in respect to all tracks, locating the point of switch where one track diverges from another. High and low water marks should be indicated on the profile at points where the line of the road crosses streams. It is customary also to locate the banks of large streams for a distance of ¼ mile or so from the point where the track crosses the stream. It is quite largely the practice to make use of photography in connection with the surveys of the line, taking a view of every company building, bridge, culvert or other structure and of each road crossing. Photographs are mounted for filing and the negatives are retained.

In relining track that has strayed from the original center stakes efforts should be made to find as many of the old reference marks as possible, particularly the points of curvature. If these cannot be found the whole line must be rerun, keeping as near the existing alignment as may be practicable. Of course there are many points which it is desirable or obligatory to consider fixed, such as the center line at bridges, points of crossing with other railways, the existing center line opposite station platforms, at water stations, through yards, etc., and these are taken for governing points on the new line. When such points come on curves where the original P C.'s have been lost some study may be required in order to get a true curve to follow the old one approximately and pass through the required points. One way to do this is to plot points on the curve at convenient intervals, as offsets from one of the tangents produced, and then to cut and try with various calculated curves until one is found to fit the conditions. In rerunning an old tangent that is found badly out of line it may pay to first plot it with reference to a preliminary tangent, using an exaggerated scale for the offsets measured from this tangent to points on the track center 400 or 500 ft. apart. By means of this plat the position for the new line which will require the least work of realigning the track from its existing location can be readily determined.

In connection with the subject of resurveys reference may be made to track information or data sheets, which are used by the maintenance of way department of most well regulated roads. These sheets or charts consist of blue prints or other drawings on which are delineated a plan and profile of the track, together with all data useful to the engineering, track and bridge departments, put down in the order in which they come. For instance, the width of right of way is shown, usually on an exaggerated scale, with intersecting line fences and the intersection angle in each case, and the names of the landowners; the kind of right-of-way fence, when built or rebuilt, and the location of snow fences; the location of stations and other buildings on the right of way, and of buildings near the right of way; the location of bridges, with their numbers, and all openings in the roadbed; the headroom at through bridges; the location of highway crossings, farm crossings, track signs, cattle guards, cuts, tunnels, culverts, ditches, switches and turnouts, with the number or angle of the frog, and various measurements between side-tracks and structures located in nearness thereto; the true bearing of tangents, the data relating to curves; the dividing points between sections, with the number of the section and the name and residence address of the section foreman; the kind of ballast, and its depth; the character of the material in cuts and fills, and the slope; other important natural conditions on or near the right of way; the weight of the rails and the date when the same were laid; the kind of joint fastening, if different kinds are used, or any devices which may be in use for experimental purposes; the location of water tanks, track tanks, mile posts, mail cranes, stand pipes, telltales, signals and in-interlocking devices—in short, the location of each thing along the track which can be of interest in any way to the maintenance of way department, should be shown and the thing described as fully as is feasible. For this purpose the drawings should be made to such scale as will allow the data to be inserted without presenting a confused appearance. The use of conventional signs aids very much in elaborating on details and in confining descriptive data to the smallest possible space; as, for instance, the kind of material in buildings and other structures or the kind of fence may be clearly indicated by conventional signs or symbols. The profile is usually drawn along the bottom of the sheet, and broken as often as is necessary to keep it from running up on or off the sheet. It shows the grades and the altitude of particular points above sea level. There should also be shown upon the sheet the location of bench marks for leveling.

The standard profile sheet of the Cleveland & Pittsburg division of the Pennsylvania Lines West shows, in addition to the grade line of the track or top of rail, a "ground line" taken 20 ft. out on each side of the track. The grade line of the track is shown in blue, the ground line on the north side in full black and the ground line on the south side in broken black. Wherever the elevation of the track varies from the established grade line a black dot is made every 100 ft. to show what that elevation is. These profiles are made in long rolls, each roll covering about 20 miles of track. The purpose of the ground lines is to enable one to make a rough estimate of the grading to be done in building a second track or a siding, or of the amount of earthwork necessary for a contemplated reduction of grades.

These drawings, sheets or charts, as they may be called, should be revised yearly, or from time to time as changes are made. For office work such a drawing can be conveniently used in the form of a scroll in two rolls, one rolling out as the other rolls up, but for outside use it may be folded into pocket size or preferably be divided into separate sheets which are bound under covers. The New York, New Haven & Hartford R. R. uses data sheets 22 ins. long and 10 ins. wide bound in book form. They are drawn to a scale of 300 ft. to the inch, showing 5000 ft. of track on each sheet. The information shown on each sheet is of a more elaborate character than is usual with most companies, giving, in addition to features already named, a great deal of information useful to the operating department, such as the taxable value of all property adjoining the right of way and the character of the land, as to whether cultivable, wooded, etc.; a list of the names of agents and other permanent employees; a list of the industries in each town furnishing business to the road; the names of hotels, and whether express wagons or carriages may be found at the station; a list of the newspapers, etc. The Pennsylvania R. R. uses a long sheet 6 ins. wide, which is folded into a form 4x6 ins. in size, for the pocket. Drawings for a right-of-way atlas are usually made to a scale of 100 to 200 ft. to the inch. The atlases of the Pennsylvania R. R. are made to a scale of 100 ft. to the inch They are drawn on tracing linen sheets, 24x36 ins., which are mounted on thin cloth, like cheese cloth, and bound into books. When maps of this kind are put up in book form they should be bound loosely or in such manner that sheets may be easily removed for correction, from time to time, and then replaced.

181. Rail Deflection.—One of the aims of engineering is to reduce the problems of practice to a basis of computation. Especially is this true of structures, where it is desired to know what duty each member must perform, in order that it may be proportioned with a view to the safety of the structure and economy of material. In modern railway work all construction is designed as nearly as possible on this plan. There are, however, certain structures environed by conditions so far removed from satisfactory analysis that calculation beforehand of the stresses from loads imposed and the determination of the behavior of the structure under stress become impracticable. In such cases the investigation of the problem is conducted along experimental lines, usually in observing the behavior of the structure and in taking measurements while the same is under stress. The track comes within this category of engineering problems, for all that we can know about the stresses to which the parts are subjected is what we are able to see and deduce from the behavior of those parts in service. In fact it may be said that, so far as railway engineers have given attention to this matter, but very little is known.

The development of railway rails and fastenings has not advanced on designs formed to meet certain known requirements of stress and deflection, because not until comparatively recent years was it known what these stresses and deflections were, with any degree of approximation. From experience it was known that rails weighing 50 lbs. per yard were strong enough for the loads when that weight of rail was in common service, and it being known that an increase in the depth of the rail, with a corresponding increase in the amount of metal, made a stronger rail, it only remained to increase the weight of rail; and such has been done, the increase in weight of rails taking place in about the same proportion as the increase in weight of rolling stock, although perhaps a little tardy at times. During comparatively recent years some information has been obtained concerning rail deflection and stresses in the same, but it has had only a passive effect, at most, so far as rail design and track construction are concerned; for beyond the mere matter of ascertaining such stresses and deflections from the few experiments performed no attention has been given to the matter of making use of the data in practical ways.

It would seem that track deflection experiments could be made a fruitful field of investigation. In connection with what is said above regarding development in the weight of rails it may be stated that, generally speaking, rails have been strong enough against breakage, but the main question always has been, and is still, as to what is the most economical weight of rail for maintenance of track surface. There is some certain amount of money which can be expended for metal in the rails which will yield a maximum economy in track maintenance, but as to just what the proper weight of rail is for an assumed volume of traffic is not known with any close degree of approximation. We know that it costs less to maintain the surface of track laid with 80-lb. rails than track laid with 60-lb. rails, but just how much less is not definitely understood. It would seem that a carefully conducted series of track deflection experiments with rails of different weight per yard, laid at different times on the same ties and roadbed, taking observation of the deflection and rate of recovery of the ballast and roadbed and the amount of permanent deflection of the same during certain intervals, might lead to more definite knowledge of the relation of rail deflection to track settlement than we have at present. There are other matters of investigation of measurable importance referred to further along. In the mechanical department of railways, tests are made of fuel, engine working, axle grease, etc.: why should not tests be made of the track and roadbed, which represent a larger investment than all other railway property?

A number of track deflection experiments carried out under the auspices of Mr. James E. Howard, of the United States arsenal testing plant at Watertown, Mass., are of record and are prominently known. The first of these were made on the Boston & Albany R. R., in 1889, and later on others were conducted as follows: On the Chicago, Burlington & Quincy Ry., in 1893; on the Pennsylvania R. R., in 1894; and on the Boston & Albany R. R. again, in 1895. It is interesting to review the data obtained from these experiments, not so much in contemplating the actual deflections observed and the ascertained stresses in the rails, as in the study afforded by the variation of the deflections under different conditions, and the irregularity of the results from like causes acting at different points on the same rail and on different pieces of track.

Experiments on the C. B. & Q. Ry.—The experiments conducted on the Chicago, Burlington & Quincy Ry. were under the supervision of Mr. Howard, assisted by Mr. F. A. Delano, at that time superintendent of freight terminals of the road. They were made at Hawthorne, Ill., during the month of October, when the ground was in settled condition. The experiments in track deflection were of two classes: First, the deflection of the rail was measured at a certain fixed point on the same, under each wheel of the locomotive, which was made to change its position at each observation, and also when the locomotive was in position to bring the point on the rail midway of the space between each two adjacent wheels. In the other class of experiments the level of the unoccupied rail was carefully taken, after which the locomotive was run into position and the level of the rail taken at various points while under load. At first the depression of the rail was taken by leveling with an astronomical spirit bubble and micrometer screw from bench marks established on stakes driven into the roadbed 31 ins. from the rail, but it was soon found that the depression of the ground extended beyond the stakes, when the bench marks were dispensed with and the leveling was done from a cantilever supported 10 ft. from the rail. The levels taken from the stakes were then corrected for the depression of the same due to the proximity of the locomotive. As the result of careful measurements it was found that opposite the main driver of a mogul locomotive weighing 125,000 lbs. the cinder ballast at a point 31 ins. from the rail was depressed .047 in.; at a point 61 ins. from the rail it was depressed .013 in. and at a point 91 ins. from the rail the ground was depressed .001 in. At a point 10 ft. from the rail no noticeable depression could be detected. At a point 31 ins. from the rail, in gravel ballast, the depression was .036 in. The rail in this track weighed 66 lbs. per yard. It should be explained that the ground underneath the track where these experiments were made was of firm clay and the spikes were redriven before the experiments began.

The fiber stresses in the rails were determined by measuring the amount of elongation or compression of the rail flange by a micrometer (Fig. 523) extending over a gaged length of 5 ins. on the top of the rail flange, observations being taken of the strains when the wheels were directly over the micrometer and in all positions of the engine when the micrometer stood midway of the spaces between the wheels. On an assumed modulus of elasticity of 30,000,000 lbs. per sq. in. the stresses were computed for the fibers on the top of the rail flange and it was then assumed that the fiber stresses on the bottom of the flange (which are the ones referred to in connection with these experiments) were proportional to their distance from the neutral axis of the rail.

Before taking observations of the depression of the rail under load measurements were taken of the wave in the rail running in advance of the locomotive. With a mogul locomotive weighing 125,000 lbs., on track laid with 66-lb. rails on oak ties, in cinder ballast 8 ins. deep it was found that an upward movement of the rail began when the leading wheel was 15 ft. away and the crest of the same (about .0035 in. high) was reached when the locomotive was 8½ ft. away from the point observed. Then followed a sudden depression and when the locomotive had approached to a point 7½ ft. from the point of observation the rail had subsided to its normal level or hight.

One of the locomotives (No. 336 Class H) used in these experiments was a mogul weighing 110,000 lbs., with wheel spacings and weight distribution as shown in Fig. 403. With this engine standing in one position on main track laid with 66-lb. rails, 17 oak ties to the rail, gravel ballast, in such position that the truck wheel and first driver spanned the joint, the depression of the rail was as noted on the diagram. The maximum depression was .156 in., under the main driver. The depression at points between the drivers is recorded on the diagram. The line below the shaded part of the diagram measures the correction of each observation for the depression of the bench mark due to the proximity of the locomotive. With the same engine in different positions on the same piece of track it was found that at a point 26 ins. from the joint the rail was depressed .111 in.—.160 in.—.161 in.—and .151 in. as the truck wheel and each of the drivers respectively were run into position over the point observed. With the wheels spanning the point (that is when the engine was in such

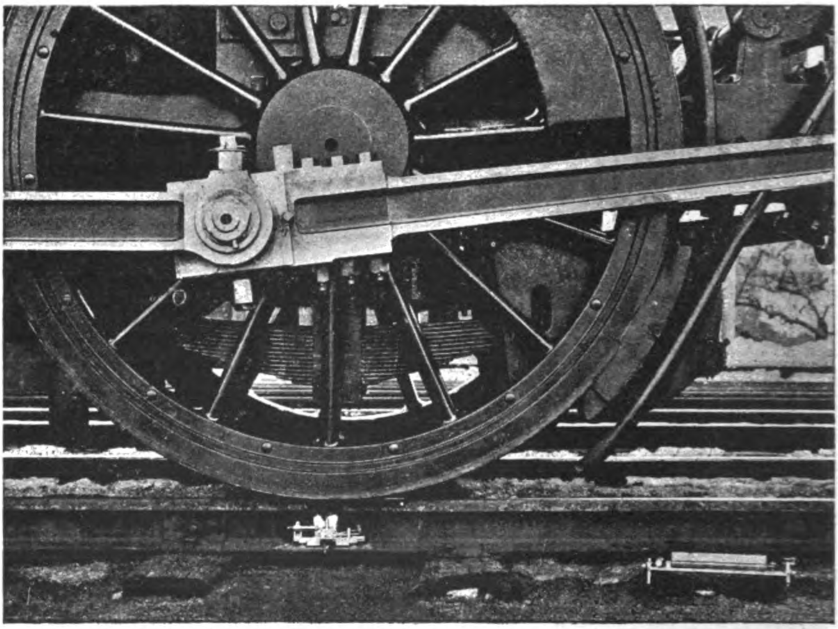


Fig. 523.—Micrometer for Measuring Strains in Rails.

position that the point observed was midway of a space between wheels) the deflection was .035 to .045 in. less in each case than the average of the deflections under the two adjacent wheels. The bottom of the rail was in tension as each wheel passed over the point observed, and either in compression or in a state of neutral stress as each two adjacent wheels spanned the point. The deflection of the rail under each of the tender wheels was quite uniform, the maximum being .112 in. for the first and second wheels each from the engine, and the minimum .092 in. for the rear wheel. The depression of the rail when each two of the adjacent tender wheels spanned the point of observation averaged about .009 in. less than the average of the above depressions in each case. With the rear driver and front tender wheel spanning the point the depression of the rail was .097 in.

With the same engine on the same piece of track, in different positions, the fiber stresses per square inch, as measured at a point on the base of the rail 9 ft. 9 ins. from the joint, were as follows, beginning with the truck wheel over the point observed and referring to each position of the engine when the point observed was under each wheel and midway of each of the wheel spacings: 7470 lbs. tension—750 lbs. compression—10,450 lbs. tension—0 lbs. stress—10,450 lbs. tension (middle driver)—10,450 lbs. tension (under rear driver).

With another mogul locomotive (No. 524) of the same class weighing 125,000 lbs., on the same piece of track, observations being taken at a

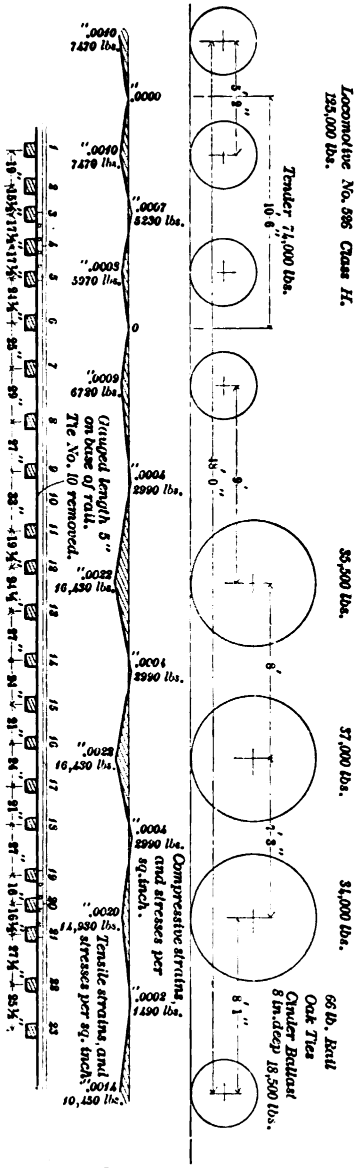


Fig. 525.—Experiments in Track Deflection (For Depressions See Fig. 452).

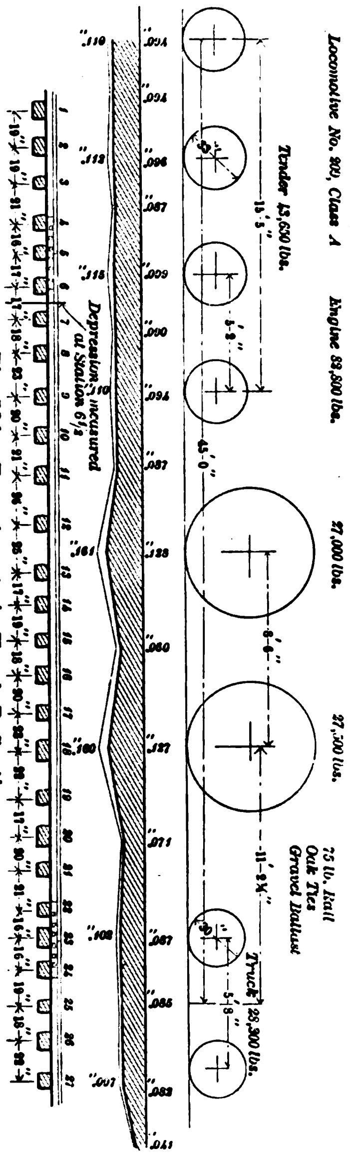


Fig. 524.—Experiments in Track Deflection.

point 8 ft. from the joint, there was a maximum depression of .182 in. under the middle driver, and about the same deflection for each of the other two drivers, The distribution of the weight and other details are shown in Fig. 476.

Another mogul engine of the same class weighing 110,000 lbs was run upon side-track laid with 66-lb. rails and oak ties (16 to the rail length) in cinder ballast 8 ins. deep. The depression of the rail at a point 8 ft.

2 ins. from the joint was .218 in., .230 in. and .206 in. under the three drivers respectively, front to rear. The depression from the truck wheel was .155 in.

With another engine (No. 526) of the same class weighing 125,000 lbs., on the same piece of cinder-ballasted track, there was a maximum deflection of .252 in. at the first driver, the point of observation being at a point on the rail 11 ft. 7 ins. from the joint, where a tie had been removed, leaving a space of 33 ins. center to center of ties. It is to be regretted that no observations were taken at this point before the tie was removed. The deflections as each of the drivers passed this point were practically the same, being .250 in. and .244 in. for the middle and rear drivers, respectively, as shown by diagram in Fig. 452. The maximum stress in the rail at this point was 16,430 lbs. per sq. in., tension, being the same for both the main and rear drivers (Fig. 525). The tensile stress under the truck wheel was 10,450 lbs. per sq. in. The maximum compressive stress was 2990 lbs. The data in inches on the strain diagram shows the amount of stretch or compression of the rail flange. Observations taken 6 ft. 4 ins. from the joint on the same piece of track with the same engine showed a maximum tensile stress of 13,810 lbs. per sq. in. when the middle driver was over the point, and a maximum compressive stress of 4480 lbs. per sq. in. when the front and middle drivers were spanning the point. The tensile stress under the truck wheel was 8960 lbs. per sq. in.

Observations made on rails weighing 75 lbs. per yd. were with locomotives of different type and weight, so that comparisons are not as instructive as would be the case had the same locomotives been used on both the 66-lb. and 75-lb. rails. Observations were taken with an 8-wheel passenger engine weighing 82,800 lbs. (Fig. 524). The track was a stretch of main line laid with 75-lb. rails and oak ties (18 per rail length) in gravel ballast. The point of observation was 25½ ins. from the joint and the depression under the front and rear drivers was .160 and .161 in. respectively, or the same as were observed for the mogul locomotive No. 336 (Fig. 403), and under practically the same track conditions, thus showing the relative severity of this class of locomotives. In all of the above experiments the point of observation was taken on the rail midway between ties. The depressions under a 6-wheel switch engine (No. 466) are shown in Fig. 480.

From these experiments it appears that the leading truck wheel develops a higher average unit fiber stress than the other wheels, in proportion to the weight on the same, and it is not always the case that the greatest depression or the greatest stress takes place under the heaviest wheel load, as either may depend to considerable extent upon the spacing of the wheels, the distribution of the weight, the spacing and tamping of the ties, and earth conditions. It was found that the recovery of the roadbed from the depression was not complete immediately upon the removal of the locomotive from the vicinity. While the principal part of the recovery took place at once a small portion of the depression was very sluggish in returning to the normal hight. The length of time required for the complete return of the roadbed to its normal state was not determined.

Experiments on the P. R. R.—The track experiments on the Pennsylvania R. R. were made during the months of October and November, 1894, with two eight-wheel passenger engines (Nos. 809 and 1515) and a consolidation freight engine, No. 557. Engine No. 809 weighed 127,050 lbs. of which 87,300 lbs. was about equally distributed on the four 80-in. drivers. The wheel spacings, from front to rear, were 6 ft. 7 ins.—8 ft.

5½ ins.—7 ft. 9 ins. (between drivers). Engine No 1515 weighed 145,500 lbs., of which 95,200 lbs was carried on the 84-in drivers, the first pair carrying 48,500 lbs. and the second pair 46,700 lbs., which, it will be noted, is very heavy, the load on the front drivers exceeding 12 tons per wheel. The wheel spacings, front to rear, were 7 ft. 8 ins.—8 ft. 3¾ ins.—8 ft. (between drivers.) Freight engine No. 557 weighed 124,800 lbs., of which 113,800 lbs. was carried on the 50-in drivers, distributed 26,500 lbs.—27,500 lbs.—31,300 lbs.—28,500 lbs., on first, second, third and fourth driver axles, respectively. The wheel spacings, front to rear, were 7 ft. 11 ins. (between truck wheel and first driver)—4 ft. 7 ins.—4 ft. 8 ins.—4 ft. 7 ins.

The object of these experiments was to determine the fiber stresses in the rails, measure the depression of the rails and find the slope or inclination of the rails caused by their depression under the weight of the different wheels. The observations for depression and data for the computation of stresses were taken in the same manner as in the experiments on the C., B. & Q. Ry. the year previously. The slope or inclination tests were made by means of a sensitive level bubble (Fig. 523) mounted on a frame 12 ins. long, having at one end a fixed support drawn to a conical point and at the other end a screw micrometer, as a means of adjustment. The method of using the instrument was to place the conical points in center punch marks 12 ins. apart on the rail flange, adjusting the instrument to level before and after the rail came within the influence of the locomotive pressure, and then note the difference in the readings. The rails examined ranged in weight from 60 to 100 lbs. per yard, being supported on oak pole ties, in stone, gravel and cinder ballast. The observations on the various rails were all made at a point on the rail quarter, with the engine in different positions. Altogether 45 distinct sets of observations were taken and diagrams were recorded from the data obtained.

Among the numerous observations were a number taken to compare the unit fiber stresses on the under side of the rail flange, under the wheels of the same locomotive on rails of different weight per yard. Thus, the average tensile stresses per sq. in. under each of the drivers of locomotive No. 809 for 60-lb., 70-lb. and 85-lb. rails, respectively, were 10,985 lbs., 17,930 lbs. and 11,820 lbs. The track in each case was ballasted with gravel. From these results it appears that the stresses in the 60-lb. rails were less than in either the 70-lb. or 85-lb. rails. With the same engine on stone-ballasted tracks laid with 60-lb., 70-lb., 85-lb. and 100-lb. rails, respectively, the corresponding average tensile stresses for each of the two drivers were 19,540 lbs., 14,390 lbs., 9675 lbs., and 9840 lbs., per sq. in. The peculiarity in this set of observations was that the stresses in the 100-lb. rail exceeded those in the 85-lb. rail. The average tensile stress per sq. in. under each of the four drivers of freight engine No. 557 corresponding to 60-lb., 70-lb., 85-lb. and 100-lb. rails in stone-ballasted track, were 14,125 lbs., 7910 lbs., 7160 lbs., and 5090 lbs., respectively.

The fact that the lighter of two rails in the first two sets of experiments underwent smaller stresses for the same loading is not necessarily an indication of disproportionate stiffness. It must be taken into consideration that underneath a locomotive or car there are four supports which undergo depression and stress: the rail, the tie, the ballast and the roadbed. In view of the variable stability of the roadbed it is not surprising that a rail of given weight per yard should undergo smaller stresses than a heavier rail on another piece of track, for the conditions of earth support in the two cases may have been entirely different, and it does not necessarily follow that increased stiffness in the rail could produce a greater stiffness for the whole supporting structure, as between the two locations compared. In fact such results are just what an experienced trackman would expect. It should be borne in mind therefore that in any investigation of the depressions in track or stresses in the rails, not only must the relative stiffness of the rail be considered, but the relative supporting powers or properties of the ballast and roadbed, in each case. As a means of illustration, the variable resistance found in driving piles at different locations in the same vicinity may be considered.

For the purpose of determining the relative supporting power of various kinds of ballast observations were taken of rails of the same weight laid on tracks in different kinds of ballast, the same locomotive being used in each case. With locomotive No. 809, on 60-lb. rails, the order of rigidity was with gravel, stone and cinder, the corresponding average depression under each of the two drivers being .073 in., .162 in., and .230 in. In another set of observations on tracks laid with 70-lb. rails the order of rigidity was found with gravel, cinder and stone, the average depression under the drivers, corresponding to the different kinds of ballast, being .138 in., .230 in., and .277 in. These observations would seem to make it appear that gravel is a more rigid ballast than either stone or cinder, but in some observations with the same engine on tracks laid with 85-lb. rails the order of rigidity was stone and gravel, the corresponding average depression for the drivers being .144 in. and .233 in. Thus again are we obliged to fall back upon the variability of earth support at individual rails in order to account for the phenomena observed.

It may be of interest to compare the stresses in the rails under the two passenger locomotives Nos. 809 and 1515, as showing the effect of increase in wheel weights. On cinder-ballasted track laid with 85-lb. rails the average tensile stress per sq. in. under each driver of engine No. 809 was 10,030 lbs., while under each driver of engine No. 1515, at the same point on the same piece of track, it was 11,820 lbs. On gravel-ballasted track laid with 85-lb. rails the average tensile stress under each driver of engine No. 809 was 11,820 lbs. per sq. in., while under each driver of engine No. 1515, at the same point on the same piece of track, the average tensile stress per sq. in. was 16,800 lbs.

It is also instructive to compare the stresses produced by the drivers of freight and passenger engines of about the same weight, and as passenger engine No. 809 is but 1.8 per cent heavier than freight engine No. 557, a good opportunity for a fair comparison is here afforded. On cinder-ballasted track laid with 85-lb. rails the average tensile stress per sq. in. for each driver of the passenger engine was 10,030 lbs., and the maximum tensile stress the same. The average tensile stress under each driver of the freight locomotive at the same point on the same piece of track was 5910 lbs. per sq. in., and the maximum stress 10,030 lbs. per sq. in. On gravel-ballasted track laid with 85-lb. rails the average tensile stress per sq. in. under each driver of the passenger engine was 11,820 lbs. and the maximum stress 12,180 lbs., while the average tensile stress per sq. in. under each driver of the freight locomotive at the same point on the same piece of track was 7700 lbs., and the maximum stress 10,030 lbs. On stone-ballasted track laid with 85-lb. rails the average tensile stress per sq. in. under each driver of the passenger engine was 9670 lbs., and the maximum stress 10,750 lbs.; while for each driver of the freight locomotive, at the same point on the same piece of track, the average tensile stress was 7160 lbs., and the maximum stress 10,030 lbs. The compressive stresses for the rail between the wheels are not mentioned, owing to the fact that in each case they were far less than the tensile stresses under the wheels, the average ratio of the two kinds of stress for the passenger engine being 37 to 100 and for the freight engine 36 to 100. It thus appears that in each comparison of the effects produced by the two engines on the same piece of track the average stresses produced by the freight engine drivers were far less than those produced by the drivers of the passenger engine (ranging from 60 to 75 per cent), while in no case did the maximum stress for the freight locomotive exceed that for the passenger engine. The conclusion to be drawn from these results is that locomotives of the eight-wheel type exert greater pressures upon track than consolidation locomotives of the same weight.

In this series of experiments several sets of observations were taken to show stress effects under special conditions. Thus in one instance a tie was removed from stone-ballasted track laid with 100-lb. rails, leaving a space of 52 ins., between centers of tie supports. The maximum tensile stress per sq. in. in the flange of the rail, developed under one of the drivers of engine No. 809, was 18,970 lbs., while the maximum stress per sq. in. on another rail of the same section (in stone ballast), where the ties were spaced 26 ins. centers, was 9840 lbs. In a test on a 34-in., six-bolt angle bar at a suspended joint between 70-lb rails, with joint ties 21¾ ins. centers, the bottom leg of the splice bar underwent a maximum stress of 22,140 lbs. per sq. in. when one of the drivers of passenger engine No. 809 stood directly over the joint. With the drivers spanning the joint there was a compressive stress of 8300 lbs. per sq. in. In a test made with the same engine on track laid with 70-lb. rails and oak ties 12 ins. apart in the clear, on an iron girder deck bridge, a maximum tensile stress of 18,180 lbs., per sq. in., was found in the flange of the rail when one of the drivers stood over a point midway between ties.

Experiments on the Boston & Albany R. R.—The experiments on the Boston & Albany R. R. were made in February, 1895, on track laid with 95-lb. rails on yellow pine ties, with shoulder tie plates, in gravel ballast, which, at the time, was frozen. It is interesting to compare some of the results obtained with the observations made on the 100-lb. rails of the Pennsylvania R. R. The depression of the rail at a point in the rail quarter, under each driver (69-in.) of an eight-wheel passenger engine weighing 115,700 lbs. and carrying 37,500 lbs. on each driver axle, was .140 in. It was found, however, that by redriving the spikes before making the test at a quarter point on another rail the depression under each driver was reduced to .085 in. The tensile stress in the rail flange at a point on the rail quarter midway between ties spaced 24 ins. centers, was 6870 lbs. and 9160 lbs. per sq. in., under the front and rear drivers, respectively. The tensile stress under the front truck wheel in this test was high, being 6100 lbs. per sq. in. In seven tests made at various points on a rail, including the rail joint, quarter and center, the maximum tensile stress was found to be 11,450 lbs. per sq. in., under the rear driver, at a point on the rail quarter. In observations on track in frozen ballast it is doubtful if any finely drawn conclusions are of any value, since the conditions of tie support depend so largely upon the manner of the heaving of the ground; and then the depth to which the roadbed is frozen, underneath the ballast, would make all the difference imaginable, since if only the ballast was frozen the support for the track would be only partially affected.

In this account of track depression and stresses in the rails the space devoted to the subject has permitted only a general consideration, making use of typical examples. The reader who wishes to go into the subject in detail is referred to the government reports on "Tests of Metals and Other Materials," at the Watertown Arsenal, Mass., for the years 1894 and 1895.

In the track deflection experiments considered hitherto the observations of depression and strain were taken with the locomotive at rest, so that the behavior noted of the rails and track was with statically applied or quiescent loads. During subsequent years means have been devised and used for measuring track depression and rail strains under trains at speed These experiments are of course more interesting, as then the track is put to test under more severe, but nevertheless working, conditions. Such experiments in this country, confined to the measurement of strains in the rail flange, have been conducted by Mr. P. H. Dudley, with an instrument of his invention known as the "stremmatograph." This instrument consists of a micrometer clamped to the under side of the rail flange, over a length of about 5 ins., and provided with a scriber point which moves in unison with the elongation or compression of the metal. The record is taken on a strip of polished copper, which is moved at right angles to the rail and across the direction of movement of the scriber point, while an engine or train is passing over the rail. In using the instrument the scriber point is set for recording, and when the train is within a rail's length the metallic strip is started and moved continuously while the wheels are passing. The fluctuating movement of the scriber point, due to the stretch and compression of the rail fibers, traces upon the moving metallic strip a curve whose ordinates, measured to a reference line drawn before starting, denote the strains in the metal for the various wheel loads. From these strains the unit fiber stresses of the metal are computed.

By means of this instrument Mr. Dudley has obtained a great deal of information on rail stresses under moving trains which has enabled comparisons to be made showing the effect of speed. Thus, for instance, in comparing data obtained with the same engine, moving at speeds of 2 and 10 miles per hour, it was ascertained, from an average of the tensile and compressive stresses in the rail under and between all of the wheels, that at the higher speed the stresses in the rail were increased 14.3 per cent over the stresses which took place in the rail at the slower speed. A record taken on the New York Central & Hudson River R. R. at West Albany, N. Y., on a 5-in., 80-lb. rail laid on ties spaced 25 ins. centers, in gravel ballast, while an 8-wheel engine weighing 118,950 lbs., with 40,000 lbs., 41,950 lbs. and 37,000 lbs., on truck, main axle and rear axle, respectively, hauling five Wagner palace cars passed at a speed of 40 miles per hour, showed the following stresses per square inch on the under side of the rail flange: Compression in front of truck wheel, 1417 lbs.; tension under front truck wheel, 13,070 lbs.; tension under rear truck wheel, 12,579 lbs.; tension under front driver, 31,415 lbs.; tension under rear driver, 26,456 lbs.; average tension under car wheels, 12,720 lbs.; maximum tension under car wheels, 16,534 lbs.; minimum tension under car wheels, 9448 lbs.; maximum compression between engine wheels (rear truck wheel and front driver), 5433 lbs.; average compression between engine wheels, 3247 lbs.; average compression between tender wheels, 1810 lbs.; average compression between car wheels, 2057 lbs. The maximum compressive stress per square inch found between car wheels was 4960 lbs.—between the rear wheel of the fourth car and the front wheel of the fifth car. All the compressive stresses between the trucks of different cars were in excess of the average compressive stresses between wheels of the same car. The weight of the cars was in the neighborhood of 100,000 lbs. each.

In view of the above data it is interesting to contemplate the severity of the service imposed upon a rail, even at that moderate speed, due to the rapid reversal of the stresses. At a speed of 40 miles per hour a train runs 58 ft. 8 ins. per second—a distance which extends over the entire wheel base of the engine and tender and past the first wheel of the car following, or past nine wheels. That is to say, nine wheels pass over any given point in the rail per second, each causing a reversal of stress amounting to thousands of pounds per square inch, as indicated.

Comparing records obtained from an 80-lb. rail in gravel-ballasted track, with records obtained from a 100-lb. rail in stone-ballasted track, a 63-ton engine moving at a speed of 20 miles per hour developed tensile stresses of 11,574 lbs., 12,046 lbs. and 14,172 lbs. per sq. in., under front truck wheel, front and rear drivers respectively, on the 80-lb. rail; as against stresses of 10,865 lbs., 4960 lbs. and 9448 lbs. per sq. in., for front truck wheel, front and rear drivers respectively, on the 100-lb. rail, from an engine of the same weight and class running at a speed of 19 miles per hour. In all of the experiments on 100-lb. rails in stone-ballasted track, so far as reported, the strains produced by one or the other of the truck wheels (the front wheel in every case but one) exceeded the strains produced by either of the drivers; whereas on 80-lb. rails in gravel-ballasted track the strains produced by the drivers were the larger. With switching engines having no truck the maximum stress was found under the front driver. A comparison of the stresses produced by such an engine on 65-lb. and 100-lb. rails is especially interesting. The engine was six-coupled, carrying the entire weight of 125,000 lbs. upon the drivers. The speed of the engine and kind of ballast are not stated, but tie plates were in use. With the instrument between ties spaced at 30 ins. centers the stresses in the 65-lb. rail were 51,694 lbs., 22,445 lbs. and 23,856 lbs. per sq. in., for the front, middle and rear drivers respectively, while in the 100-lb. rail the stresses were 8031 lbs., 6849 lbs. and 6142 lbs. per sq. in. for the drivers in the same order.

The records from the stremmatograph show that the dynamic effects from the wheels increase with the speed of the train and with roughness of the rails and treads of the wheels. The record above presented for the speed of 40 miles per hour shows that the stresses were about double the static effects from the same wheel loads, or about double what they were found to be when the engine was just moving over the track without exerting much tractive force. With 8-wheel engines using steam in accelerating the train it appears that much the largest stress takes place under the front driver, which is undoubtedly due in some degree to the vertical component from the thrust and pull of the main rod, as explained in connection with the subject of excessive counterbalance. With engines having more than two pairs of drivers the stresses under the middle driver were usually less than those under the other two drivers. When engines were working hard the stresses were also increased under all the wheels, compared with their average values for the engine running at the same speed but exerting only a small tractive force. With engines running at high speed the position of the counterbalance at the instant the wheel passed the stremmatograph (as shown by instantaneous photographs) had an important effect, as indicated by the strains measured. The tests further showed that the stresses per ton of loading were less for engines having more than two pairs of driving wheels than was the case with the 8-wheel type of engine. The deformation of the roadbed was decidedly less for 10-wheel and consolidation types of engines than was the case with the 8-wheel type. As a general thing, the closer the wheel spacing of the engine the less the fiber stresses per ton of load.

On the whole, it appears that maintenance-of-way engineers in Europe have given more attention to track experiments than have the engineers of this country, and as a rule they have gone into the subject with greater elaboration. On this point it will suffice to describe briefly a series of interesting experiments performed on the Warsaw-Vienna Ry., by Mr. Alexander Wasiutynski, permanent way engineer. In order to eliminate as far as possible the effect of ground depression and vibration on the apparatus four brick piers 5 ft. 3 ins. square at the bottom and 3 ft. 3⅜ ins. square at the top, with layers of felt at every fifth course of bricks, were built in timber-lined pits 7 ft. square and 24 ft. 3 ins. deep, spaced 13 ft. 1½ ins. apart, c. to c., in line, parallel with the rail, and 14 ft. distant from it. The brick piers were isolated from the lining of the pits and on top of the same were laid two lines of rails 46 ft. long, on which to slide the observing apparatus parallel to the track. This arrangement permitted observations to be taken on a stretch of track of the same length, or past both joints on a rail 39 ft. 4 ins. in length. In these experiments the deflections were recorded photographically on diagrams, thus dispensing with mechanical connection with the track. The apparatus consisted of a camera arranged at the end of a telescope tube, 11 ft. 4 ins. clear of the track. The exposure was made through a narrow vertical slit upon a sensitized film, about 4¼ ins. wide and 26. ft. long, unrolled by clockwork from a cylinder at a speed of 2 to 8 ins. per second. By means of electrical connections the film was started and stopped automatically by the wheels of the train. The point of observation in each case was a spherical mirror of polished steel ⅛ in. in diameter, attached to the rail or tie, upon which was thrown a strong light from an electric arc lamp, which was reflected as an intensely bright spot, or strong enough to make an instantaneous exposure. In this manner a wavy line was photographed upon the moving film, representing the movement of the point of observation under the weight of passing wheels. Two instruments, electrically connected, were used simultaneously at a known distance apart, and by means of time-interval exposures upon the film through a small aperture above the vertical slit, it was easy to calculate the speed of the train and the distance of a wheel at any instant from the point under observation.

The track at this point was on tangent, on an embankment 5 ft. high, and on a grade of about one tenth of 1 per cent. This embankment had been built 37 years and consisted of clayey soil mixed with some sand. From borings it was found that the soil underneath the embankment consisted of fine sand with a slight mixture of silt for a depth of 33 ft. below rail level, with a layer of coarse sand mixed with pebbles and clay at a depth of 21 ft. Water was found at a depth of 24 ft., or at the foundation of the piers. The traffic at the time the observations were taken amounted to 32 passenger trains and 24 freight trains daily. The ballast consisted of gravel intermixed with coarse sand, with some earth, the depth of the ballast being 10 ins. below the ties.

In experiments to ascertain the amount of compression of the roadbed at different depths, 4-in. holes were bored at depths of 20, 39 and 59 ins., respectively, and cased with iron pipe. Pieces of pipe of smaller diameter were then placed within the casing, extending to a point within 16 ins. from the top, and the diagrams of depression were taken of the movement of marks fixed to the upper end of the inner pipe. The diagrams showed clearly a depression of the roadbed under each wheel of the locomotive at various depths, the maximum depressions being .05 in. at a depth of 20 ins. below the rail, .03125 in. at a depth of 39 ins. below the rail and .025 in. at a depth of 59 ins. below the rail. At a depth of 21 ins. below the bottoms of the ties the depression was found to amount to only one fourth to one third of the depression of the ties. Notwithstanding all the precautions taken there was found to be a slight vibration in the piers, the amount of which was ascertained by observations with the recording instruments during the passage of trains, the film being unrolled first horizontally and then vertically, to get the vertical and horizontal oscillations respectively. From careful observations it was found that the oscillation of each pier was within .003 in. vertically and .002 in. horizontally, showing that at a depth of 24 ft. below the rail and at a lateral distance of 16½ ft. from the center of the track there was sensible elastic depression of the ground.

In the experiments to determine the bending curve of 6x10-in. oak ties a six-coupled switch engine was used at a speed of about 6 miles per hour. The ties selected were the two at the middle of a 76-lb. rail 39 ft. 4 ins. long, and observations were taken on a point at the middle of the tie, at the outside of the rail seat, and at the end of the tie. In order to prevent the compression of the wood fiber from affecting the record of the depression of the tie a hole was bored through the tie and a bolt of smaller diameter carrying the point of observation was passed through the tie and made fast at the bottom. It was found that with the middle driver of the locomotive midway between tie supports the deflection of the rail extended over three ties in either direction; and with distances between the axles of the locomotive equal to two to three times the tie spacing, the maximum rail load amounted to 39 to 44 per cent of the wheel load. With ties 8 ft. long the deflections at the middle of the tie, at the rail seat, and at the end of the tie, respectively, stood in the ratio of 69 to 100 to 124, showing that the end of the tie was deflected most and the middle of the tie least. Observations on ties 8 ft. 10 ins. long showed that the deflections for the middle of the tie, rail seat and end of tie, respectively, stood in the ratio of 75 to 100 to 68, showing that on ties of this length the deflections were greatest at the rail seat and least at the end. Under 63-lb. rails the deflection of ties 8 ft. 10 ins. long was in the ratio of 91 to 100 to 78 for middle of tie, rail seat and end of tie respectively. These observations are interesting, as affording data for the determination of the proper length of tie, or a tie which should deflect the same everywhere along its whole length. From the results of these experiments it would appear that ties 8 ft. in length are too short and ties 8 ft. 10 ins. in length too long. A tie 8 ft. 6 ins. long (corresponding to a depth of 6 ins.) is probably not far from the theoretical length, for standard-gage (4 ft. 8½ ins.) track, such as was the track experimented upon.

Another series of observations was made to determine the depression of the ties at the rail seat, for different types of track. The experiments were repeated two or three times at each tie and an average was taken of the depressions of all the ties under each rail, for each type of track, so that the data obtained were not the results from chance observations. The locomotives running over the experimental section were of two types, one having six coupled drivers without truck, with a load of about 13 tons per axle, and the other an 8-wheel passenger locomotive with a load of 15 tons on each driving axle. One type of track experimented with was laid with 62-lb. rails 19 ft. 8 ins. long, on eight 6x10-in. oak ties 8 ft. long, spaced 19½ ins. centers at the joint, 26½ and 31½ ins. centers, respectively, for the next two ties, and 33½ ins. centers for the intermediate ties. The joint ties were provided with tie plates. The average depression of the ties in this type of track was found to be .0184 in. per ton of wheel pressure. The depression of the ties at the rail center exceeded the depression at the joints and quarters.

Another type of track was laid with 76-lb. rails 39 ft. 4 ins. long, on

16 ties spaced 19½ ins. centers at the joint, 21½ ins. centers for the two next ties and 31½ ins. centers for the intermediate ties. Tie plates were used on all ties. The average depression of the ties in this type of track was .0113 in. per ton of wheel pressure, or 40 per cent less than the average depression for the track previously mentioned. In this track also the depression of the intermediate ties exceeded those of the joint and quarter ties.

A third type of track was laid with 76-lb. rails of the same length and 8 ft. 10-in. ties, with the same tie spacings as in the second type just noted. The average depression of the ties for this type of track was found to be .0091 in. per ton of wheel pressure, or 20 per cent less than the deflection of the ties in the preceding type of track laid with the same weight of rail. In this type of track the depression of the ties was more nearly uniform throughout the length of the rail than in the other tests, but still the maximum depressions were found with intermediate ties. By changing the tie spacing so that the two joint ties touched each other, with the next two ties spaced 21½ and 25½ ins. centers, respectively, and the intermediate ties spaced 33 ins. centers, the average depression of the ties was found to be .0111 in. per ton of wheel pressure, or an increase of 22 per cent over the average depression for the type of track with ties of the same length differently spaced. In this type of track the depression of the ties throughout the length of the rail was more nearly uniform than was the case in the other experiments. It was found that accidental causes, such as unequal tamping of the ties and surface kinks in the rails, might, even on well maintained track, affect the depression of individual ties to the extent of 50 per cent. A large number of quite careful observations showed that the depression of the rail between tie supports was only slightly greater than its depression over the ties. The difference did not average more than .0118 inch or .3 millimeter for any of the tie spaces experimented with.

The report of these experiments disagrees on a very important point with reports of almost all other experiments of the same kind; namely, as to the effect of the dynamic action of the load. The speed of trains and locomotives from which these records were taken varied from 6 to 37 miles per hour, and it is claimed that the difference in the deflection of the rails per ton of wheel pressure at varying speeds was unimportant. It is suggested, however, that had the speeds reached 50 miles per hour or more the dynamic action of the load might have had a perceptible effect

In experiments to determine the efficiency of joint splices it was found that none of the patterns experimented with could effect continuity in the line of depression of the track. With no splices on the joint the rails were deflected independently of each other, as would be expected. By the use of plain angle-bar splices the depression of the joint was reduced to about half of what it was without any splice at all. The most efficient splice—that is the one which permitted the least depression of the joint—was a 6-bolt Z-bar splice, or an angle bar splice with vertically depending flanges between the joint ties, resembling very much the Churchill joint, used in this country, but without the base plate and lower bolts used with that device. The conclusion reached was that with any joint splice in service the depression of the joint can be reduced only approximately to the depression at the middle of the rail, and this only by spacing the joint ties closer together than the intermediate ties.

It should be explained that the different types of track—i. e., rails of different length and section, ties of different length and variously spaced, different patterns of splice bars, etc., for the different series of experiments—were all laid upon the same stretch of roadbed at different times. Subsequently the gravel ballast was removed and replaced with broken granite of $1\frac{5}{8}$ ins. size. One reason for making this change was to investigate the influence of the improvement of the ballast on the stiffness of the track, but, contrary to expectations, the results did not show an increase in this respect. Observations showed that the depression of roadbed under the ballast was affected by the type of the rail and by the length of the ties, but not by the change in the ballast. It was therefore concluded that the superiority of broken stone ballast depends upon other qualities than that of relative stiffness imparted to the roadbed underneath.

182. Variations from Standard Gage.—In the United States, Canada, England and in most of the countries of Europe (Russia and Spain excepted) the standard track gage is 4 ft. $8\frac{1}{2}$ ins. or 1.435 meters. In this country all car wheels are gaged with reference to this standard, or to what is generally known as the Master Car Builders' standard wheel gage. Nevertheless, aside from the practice of widening gage on curves, there is a large mileage of track laid to a gage of 4 ft. 9 ins. This is the gage of the Chesapeake & Ohio Ry., the Southern Ry. and of many other roads in the South. The Pennsylvania R. R. works to the principle of 4 ft. $8\frac{1}{2}$ ins. as the gage of its passenger tracks and 4 ft. 9 ins. as the gage of its freight tracks; that is, the single-track and double-track lines are laid to a gage of 4 ft. $8\frac{1}{2}$ ins., but on three-track and four-track lines, where one or more tracks are devoted exclusively to the freight service, the gage of the freight tracks is 4 ft. 9 ins.

Nominally, 4 ft. 9 ins. passes for standard gage, the half-inch variation being regarded as an irregularity of standard practice. The reasons given in explanation of this irregularity are various and not without interest. So far as the southern roads are concerned, 4 ft. 9 ins. has been the standard since 1886, when the gage of many thousands of miles of track was changed from 5 ft. to 4 ft. 9 ins. It is said that the reason for adopting this gage at that time was the impossibility, in many cases, of setting the gage of locomotive drivers back sufficiently to fit standard track. As it was practicable to set them back to fit a gage of 4 ft. 9 ins., and as that gage would accommodate all cars of standard gage, it was therefore generally adopted by the roads making the change. But experience with this gage has induced many to continue using it. Concerning the amount of side play in the wheels that is necessary for the proper running of the cars there are widely varying views, with various shades of opinion coming in between. The great majority of railway engineers consider that $\frac{3}{8}$ in. is sufficient, this being the side play of new wheels gaged to the M. C. B. standard and running on track gaged to 4 ft $8\frac{1}{2}$ ins. As the wheel flanges wear, the side play increases to double or even three times this amount. On the other hand, the people who prefer the 4-ft. 9-in. gage approve of $\frac{3}{4}$ in. of side play to start with, and the wheel flanges are allowed to wear to the limit of $1\frac{3}{4}$ ins. side play, which is certainly plenty. Others (but comparatively few in number) have taken the view that a compromise is obviously safe, and have accordingly split the difference and made the gage 4 ft. $8\frac{3}{4}$ ins. The Macon & Birmingham Ry. was one of the roads which adopted this gage as standard.

At one time there was a good deal of carelessness in gaging freight car wheels, and the tight running of an occasional pair of wheels too widely gaged was an argument in favor of retaining the 4-ft. 9-in. gage for the track. The general observance of the M. C. B. standard, which now prevails, has overcome the difficulties in this respect. Some claim to have ascertained by experiment that an engine can haul more freight cars on a gage of 4 ft. 9 ins. than on the standard gage of 4 ft. 8½ ins., but that passenger trains run steadier on standard gage, although requiring a small margin of excess power to propel them. This view concerning the easier running of freight cars with widening of the gage is much disputed, but with certain roads where the freight traffic predominates it is the chief consideration for retaining the 4-ft. 9-in. gage. Another consideration which finds some support is the recognized necessity for widening gage on curves. It is quite extensively the practice to widen gage as much as ½ in. on sharp curves, and some who incline to a preference for standard gage under ordinary conditions have adopted it (4 ft. 8½ ins.) for districts where the line is mostly straight and curvature light, but on parts of the line where there is a great deal of heavy curvature, the gage is made 4 ft. 9 ins. throughout, and no widening is done on the curves.

The preponderance of engineering opinion supports the view that the closer the track and wheel gages correspond the steadier the cars will run; and a considerable number make no exception even with curves, except where it is actually shown that widening of the gage is made necessary by the wheel base conditions of the locomotives. Such opinion is, of course, favorable to standard gage proper, and the principal objections to a gage of 4 ft. 9 ins. are as follows: The increased side play of the wheel flanges permits excessive side oscillations of freight cars, with the result that the track is frequently knocked out of line. The increased side play of the wider gage permits a greater degree of slewing or "cornering" of car trucks, particularly under heavily loaded cars that are down on their side bearings. The result is a corresponding increase in the obliquity of flange contact with the rails, increased train resistance and more rapid wear of wheel flanges. The wider flangeway through frogs required by the wider gage reduces the area of possible wheel-bearing surface and results in more rapid wear than with standard gage. A good paper ("Standard Car and Track Gages") which elaborates on some of these points was prepared by Mr. C. C. Dunn and presented before the Roadmasters' Association of America, in 1899.

The tendency is all the time toward standard gage. Occasionally a road which has maintained 4-ft. 9-in. gage will decide to make the change. and as the rails are renewed the gage is gradually drawn in without appreciable extra expense. The Indiana, Decatur & Western Ry., the New York, Susquehanna & Western R. R. and the Atlanta & West Point R. R. were some of the roads that were pursuing this policy in 1901. The experience of one engineer was stated as follows: "I had the gage of our road changed last year from 4 ft. 9 ins. to 4 ft. 8½ ins. I think the standard is much better than the wider gage, and I know that since the change the trains ride better. I see no need of 4-ft. 9-in. gage in any case."

183. Automatic Block Signals and Track Circuits.—Automatic block signals are generally arranged to give their indications under the control of a track circuit. The same device is also used in some systems of highway crossing alarms, and to some extent in connection with interlocking, as explained in § 83. The basis of a track circuit is a section of track in which the two lines of rails are insulated from electrical connection with each other and also from the abutting rails at the ends of the section. The circuit is completed by a battery (*B*, Fig. 525 A) connected across from rail to rail at one end of the section and by a relay (*R*) similarly connected at the other end of the section. The circuit is thus seen to be a closed one, and normally there is a current flowing through all parts of it. To insure good electrical connections throughout the circuit the rail joints are bonded around the splice bars with iron or copper wires fastened in holes drilled in the web or flange of the rails. To provide against breakage it is customary to use two bond wires at each joint, and as a means of protection they are commonly run behind the splice bars; that is, through the open space between the splice bar and web of the rail. In some locations they corrode more rapidly behind the splice bars than outside them, and when laid in this manner the larger part of the wire is hidden from inspection. For such reasons, pro and con, both methods are extensively found in practice. The insulation between the two lines of rails in the circuit is afforded by the wooden ties, and between rails which come in abuttal at the ends of the section insulated splice bars and joint filling are used.

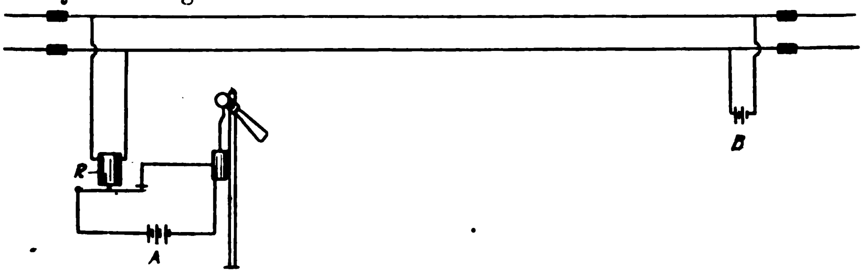


Fig. 525A—Diagram of Track Circuit.

To break the cross connection between the two lines of rails at switches, it is sometimes arranged to have the open point rail lift from the slide plates when the switch is closed. This is done by means of iron wedges spiked to the ties alongside (but not touching) the slide plates, in two or three places. When the switch is closed the open point rail rests on these wedges clear of the slide plates, but in throwing the switch to open it the open point is then moved off the wedges and let down upon the slide plates. In this position of the switch the track circuit is shunted. Another arrangement is to cut out a section of the through rail by insulating a joint each side of the switch, and then connect around the rail so cut out by means of an insulated wire run underground. By this method the track circuit is not shunted in either position of the switch. Still another arrangement is to insulate the switch rods and a joint in the lead rail. The switch-rod insulation may consist of sheet fiber placed between the clip and the point rail, with insulation bushings and washers for the bolts; or the switch rod may be cut in two in the middle, with the two pieces joined by T-ends bolted together with insulation fiber between them. At crossovers the connection is broken by insulating a joint in both lines of rails between the two tracks. At crossings with other tracks joints are insulated on either side of the crossing, on both lines of rails, and jump wires are laid underground to run around the insulated section and thus cut the crossing out of the circuit. At sidings an insulated joint is placed at or beyond the clearance point, on each side of the track, and between this and the switch there is an insulated section in the outer rail of the turnout which is electrically connected with the far rail of main line, so as to virtually form a part of the track.circuit. An engine or car on the siding within fouling distance of main line will therefore short-circuit the track relay in the same manner as would a train on main line, and hence would cause the signal governed by this track section to stand at danger. Such, in brief, describes the methods of connecting and insulating rails in simple track circuits.

In nearly all systems of automatic block signaling the track is divided into insulated sections or blocks, with a signal placed at or near the entrance to the block and a track battery at the distant end, connected as above explained. Normally there is a current flowing out of the battery into one line of rails, thence through the relay controlling the signal, and then back through the other line of rails into the other terminal of the battery. When a train arrives on the block the rails of the track circuit are connected across or shunted through the wheels and axles, and as the resistance by this path is very low compared with that through the relay, the current is short-circuited and cut off from the relay; that is to say, practically all of the current flows across through the wheels and axles and almost none through the relay. The relay then loses its magnetism and the armature drops, opening or closing a local circuit which operates or directly controls the signal and causes it to go to danger. The agency for operating the signal may be gravitation, compressed air, an electric battery (*A*, Fig. 525 A), electricity from a power circuit; or carbonic acid gas stored under pressure, in a tank at the foot of the signal post. The battery for the signal circuit is usually of higher intensity than the track battery. In any event the current in the signal circuit must be powerful enough to set in motion the mechanism which actuates the signal. In one system this mechanism is a weight and clockwork, in another it is a cylinder and piston operated by air or gas pressure through valves controlled by the signal circuit; in another it is an electric motor and in another it is an electro-magnet, either of which is usually operated by batteries in the signal circuit. After the train passes off the block (or the overlap in advance of it, in case the overlap is used) the current of the track battery again flows through its normal path, energizing the relay which controls the signal and causing the signal to be restored to its normal position. In one system the signal stands normally at clear and in another it stands normally at danger. In the "normal danger" system the signal stands at danger at all times except when cleared by a train entering the block in the rear, and this can be done only when the block in advance is clear; if it remains at danger the engineer is thereby notified that the block is occupied.

The description thus far has taken into account only one signal at the entrance to each block, and such applies to practice quite extensively. It is also common practice to use two signals at the entrance of each block: one a home signal for the block (suppose it to extend from *A* to *B*) and the other a distant signal for the next block ahead (*B* to *C*). This distant signal (at *A*) moves in harmony with the home signal (at *B*) of the block for which it gives the indications. The control of the distant signal is effected by the movement of the home signal with which it belongs, and the connection may be through a line wire or through the track circuit between them; that is, the same track circuit (*A* to *B*) controls the home signal of its block (*A* to *B*) and the distant signal for the next block ahead (*B* to *C*). The home signal (at *A*) is controlled by its track circuit and relay in the ordinary manner, but the distant signal (at *A*) is controlled by a polarized relay which is not operative except when the direction of the current through the track circuit is reversed by the action of a circuit breaker on the home signal at *B*. In automatic block signaling various types of signals are used: the disk, the banner, the banjo and the semaphore. The foregoing describes the purpose of track circuits and the manner in which certain arrangements of signals are controlled by them. It is not intended to go further into the subject of signal mechanisms, their arrangement and their operation, but as track circuits are constantly under the care of the trackmen, if not nominally in their charge, it is appropriate to consider them in some further detail.

Owing to the poor insulation of the rails from the ground it is necessary to use a track battery of low voltage. Usually it consists of two cells of the gravity type (ordinary telegraph jars) connected in the circuit in parallel, giving the same voltage as one cell but twice the current capacity. To remove the battery from the action of frost it is usually lowered into a well 5 or 6 ft. deep, consisting of a long wooden box or piece of iron pipe sunk into the ground and tightly covered. As the leakage through the ties and ballast in wet weather is usually considerable, and in proportion to the length of the circuit, it is not practicable to operate track circuits longer than 2000 ft. to a mile in length, according to the quality of the ballast. The conductivity of slag and dirt ballast are relatively high, and these materials give more trouble than other kinds. Cinder comes next, with gravel relatively low and broken stone lowest and least troublesome of all. Where the length of a block exceeds the feasible length of track circuit, two or more track circuits are used in succession, each supplied with a battery and relay. The relay of one section may be connected in to open or close the circuit next in series, or the signal wire circuit may be run through the relays of all the sections in the block.

Bearing in mind that the working principle of a track circuit is the demagnetization of the relay forming part of the same, it is obvious that a break in the circuit will accomplish the same result as the presence of a car or train on the circuit. The track circuit will therefore detect a broken rail which pulls apart, as it is very liable to do if broken in cool weather. By placing a circuit breaker in the track circuit, to be actuated by the movement of the point rails at a switch, the opening of the switch is made to do the same thing; that is, to open the track circuit and cause the signal to go to danger. The arrangement in this case is to connect the circuit breaker around an insulated joint in the track circuit, and should the insulation fail the circuit breaker would then be out of circuit and the opening of the switch might not be indicated by the signal. To provide against such danger it is usual practice to carry the signal circuit through the circuit breaker, by means of a line wire; and to make doubly sure some run both track and signal circuits through the circuit breaker at the switch. This circuit breaker opens immediately the switch rail begins to move from its closed position. As any metallic connection across from rail to rail will set the signals, the same as a train on the block, it is the practice of some roads where automatic block signals are used to insulate the cross bar of iron track gages, and the axles of hand cars from the wheels.

Insulated Joints.—The original method of insulating joints, and one that is followed extensively, is to place a fiber "end piece" or templet of the rail section in the joint opening and splice the rails with long wooden bars 3 or 4 ins. thick. To strengthen the splice as much as possible the wooden bars are sometimes reinforced with old angle bars or fish plates cut in two and separated at the middle. For insulating purposes this device is efficient, and the most reliable of any, but it possesses no strength vertically, and under heavy traffic a good deal of attention is required to keep such joints tamped to surface. The alternative type of joint splice insulation consists in lining metal splice bars with fiber sheets and using fiber bushings on the bolts. One plan is to plane off ordinary angle bars to make room for the fiber. Of the many patented devices on the market the Weber pattern is very well known and extensively used. The parts are something similar to those of the ordinary Weber joint splice (Engraving *F*, Fig. 18). There is a metal shoe angle or base plate lined with insulation fiber plate, that is used with wooden splice bars or "fillers" and fiber bolt bushings. In principle it is a wooden splice with a metal base support of L-shaped section which imparts a vertical stiffness to the joint that is much greater than that of the wooden splice bars. The Wayland insulated joint splice is similar except that the vertical leg of the angle base plate does not extend as high as the line of splice bolts, and it has in addition two bolts passing vertically through the outside wooden splice bar and the base plate. The Neafie insulated joint splice consists of a shallow steel channel for a base plate, with an insulation shim and wooden splice bars. At the ends of the base channel the vertical flanges are flattened out and punched for spikes. Each wooden splice bar is secured to the base plate by two vertical bolts. The Atlas insulated joint splice is described in §212 and illustrated by Fig. 542.

Maintenance.—The maintenance of insulated joints is a matter attended with no little trouble. Under heavy traffic the wooden fillers or splice pieces break and the insulation fiber is cut out or broken up. During wet weather the fiber becomes water soaked and rapidly deteriorates. Respecting the first difficulty, the service of the insulating material can be much prolonged by keeping the joint ties tamped up to surface. When the joint is allowed to get down or the bolts to get loose the working of the rail ends vertically breaks up the fiber and destroys the insulation. To make the insulating material impervious to water it is the practice on

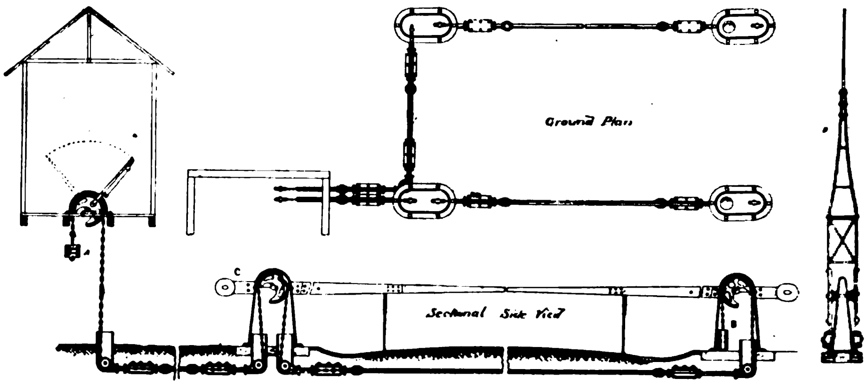


Fig. 526.—"Standard" Railway Crossing Gate.

the Chicago, Milwaukee & St. Paul Ry. to unbolt the splice occasionally, brush the parts clean of dust and oxide scale and then coat the insulating shims and liners and contact surfaces of the rail with black oil. With a view to reduce leakage from rail to rail during wet weather, as far as may be practicable, the ballast should be dressed off clear of the rails. As old rails are usually covered with oxide of iron, which is a poor conductor, the leakage of current between them through contact with the ballast is less than from new rails. It is said that the leakage through ties treated with chloride of zinc is considerably more than through untreated ties.

184. Crossing Gates.—At busy highway crossings in towns and cities, and in many other places where the view along the track is obscured by curves, buildings, trees, etc., railroad companies are frequently required to give warning of approaching trains. This is done either by a flagman stationed at the crossing, by automatic alarm bells or by railway gates. Automatic crossing alarms are usually worked by electricity, being controlled either by track circuits with batteries, like automatic block signals, described in the previous section, or by a circuit opened and closed by the motion of a treadle that is actuated by the wheels of the approaching train, or by the undulations of the rail underneath the same. Such a treadle, known as a "track instrument," consists of a lever pivoted to bring one arm at the side of the rail head and slightly above it, so that it will be depressed by passing wheels; or this arm may extend under the base of the rail and receive its motion from the undulations of the same while trains are passing.

The typical railway crossing gate consists of a light wooden arm swinging vertically on a post at the curb line. At narrow streets or roads the arm may reach entirely across the highway, but where this is not practicable a gate is placed on either side of the street and the swinging arms meet in the middle. As travel must be shut out from both sides of the railroad, this arrangement, which is quite general, requires four gates. The gate arms are sometimes as long as 55 ft., and in some cases where trolley wires would interfere with the movement of a straight arm, the latter is jointed at a suitable point and the end section folds up automatically like a jack-knife, while the arm is swinging past the wire, and extends the gate when the arm is lowered. To obstruct the sidewalk behind the gate post there is usually a short arm (Fig. 527) geared to swing in unison with the longer arm that extends across the street. The gate posts usually stand about 4 ft. high, and to minimize the force required to operate the gate the arm is counterbalanced (*C*, Fig. 526). The simplest arrangement for operating the gates of a crossing is a crank on one of the posts geared to the arm, with underground chain or wire connections with the other posts. It is preferable, however, and most extensively the practice, to have the gateman and the means for operating the gates in an elevated cabin or tower, from which a clear view may be had along the track. The means for operating the gates from a tower may be a lever, with chain or pipe line connections with the posts, or an air pump with pipes for conveying pressure to mechanisms at the posts.

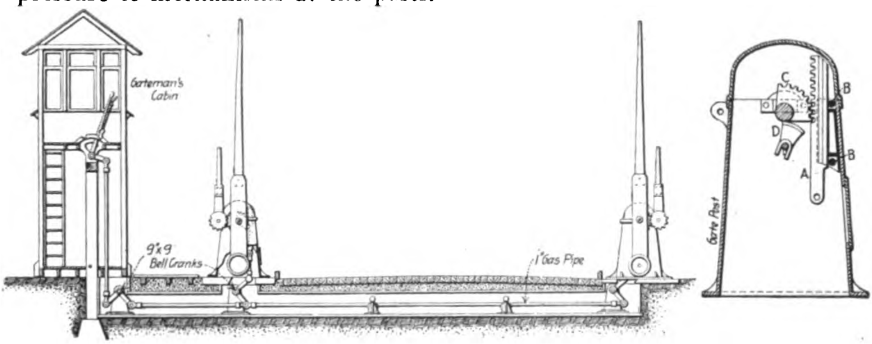


Fig. 527.—Wilson Railway Crossing Gate.

Some lever gates have a double connection or return wire between the tower and the posts, but to avoid multiplicity of parts the "Standard" gate (Fig. 526) is worked by a "single connection" or one line of wire and chain, thus saving one line of pipe for each pair of gates, and half the number of wires, chains and sheave wheels. This arrangement is accomplished by weights at the two ends of the chain, the weight *A* in the tower counterbalancing the weight *B* in the post, so that the same force is required to throw the lever in either direction. The underground wires and chains are carried in 1¼-in. pipes fitting into cast iron sheave boxes or "boot-legs" extending up inside the posts far enough to prevent surface water from finding its way into the pipe. In a four-post installation there are three lines of pipe—one between each pair of posts and one under the track. Number 4 galvanized steel wire and $^9/_{32}$-in. short-link crane chain are used. To prevent the gates from being blown down by the wind the levers are latched.

The Wilson railway gate (Fig. 527) is a lever gate with pipe-line and bell-crank connections similar to those of an interlocking plant, and of standard sizes. The pipe line from tower to gates and under the highway is supported upon the ordinary pipe carriers, and the movement of the pipe is transmitted to the arms through the rack bar *A* meshing with the segmental pinion *C*, shown in the figure. The back of the rack bar is supported by the rollers *B*, and the arm shaft is carried by the rocker bearings *D*. A 7-in. stroke of the pipe line rotates the shaft a quarter turn and raises or lowers the gates. As the levers are provided with sectors and latches the gates cannot be pushed up by persons in the street or carried down by the force of the wind.

In pneumatic gates there are two designs. Gates of the Chicago pneumatic pattern are operated by cylinders and pistons inside the posts. The Bogue & Mills pneumatic gate is operated by a rubber diaphragm in an air-tight ()-shaped chamber placed at the foot of the post and outside of it, as shown in Fig. 528. Where there is a single arm covering the entire roadway (No. 1 pattern) the gate is raised by pumping air against one side of the diaphragm and lowered by pumping against the opposite

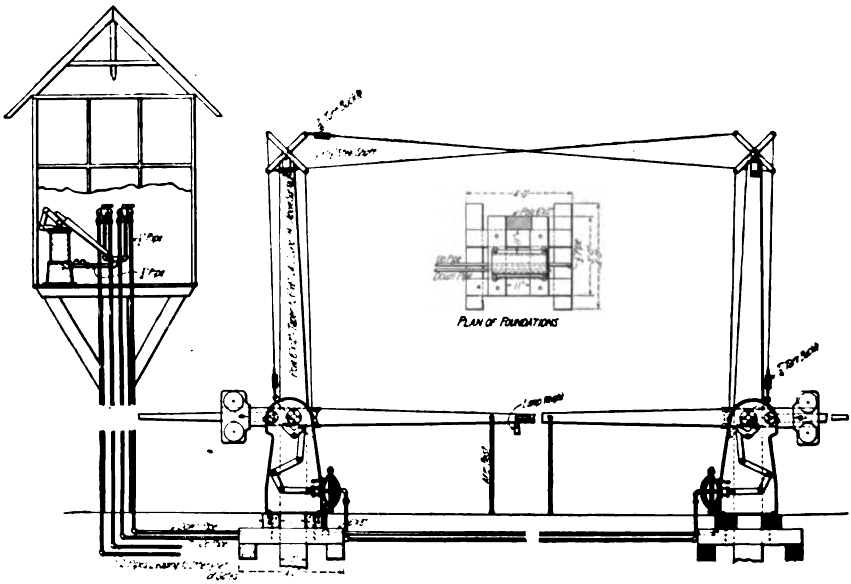


Fig. 528.—Bogue & Mills Pneumatic Railway Gate.

side. In the tower there is a cock and valves for each pair of gates which admit pressure to either side of the diaphragm and simultaneously open the other side to the outside air. In the case of the No. 2 gate, that is, where the arms protecting the roadway are double, being operated through posts from each side of the street, one of these posts has the function of lowering the arms and the other post the function of raising them. In the first instance, the air is applied on one side of the diaphragm in the down post, to lower the gates, and to raise them the air is applied to the diaphragm in the post on the opposite side of the street. The gates are worked at a pressure of 2 to 4 lbs. per sq. in., and in their down position they are locked fast. In operation it is desirable to have the two gates on opposite sides of the street move simultaneously, so as to come down together. The tendency, especially in windy weather, is for the gate nearest the tower, which receives the greater pressure, to respond more quickly than its mate, arriving at the down position while the arm on the opposite post is still at a considerable angle from the horizontal, or high enough to permit a team to pass under. To prevent this unequal action of the two arms with pneumatic gates it is necessary to have positive connection between the two. One plan is to use an underground rod connection, enclosed in a pipe with stuffing boxes at both ends to prevent the entrance of water to freeze and obstruct the operation. The installation of this arrangement necessarily requires tearing up the street, which, under a street paved with asphalt, brick or other carefully laid material, would be expensive. In order to avoid trouble of this kind the No. 5 gate of the Bogue & Mills system is designed for simultaneous operation of both arms by means of overhead wires, the operation of which is made clear in Fig. 528. Beside each gate post, there is a pole, usually 6x12 ins., tapered to 6x6 ins. at the top, the ordinary length being 24 ft., the pole standing 19 ft. above the surface; although the pole can be made of any length required to carry the tie wires above trolley or other wires. The pole is bolted to the foundation of the gate post. The overhead connection is by means of galvanized wires running from cross arms placed at the tops of the poles, with turnbuckles inserted for the purpose of adjustment. At streets of ordinary width this overhead connection is used to operate the arm on the far side of the street, the post supporting the same being "dead," so that no underground connection, requiring the pavement to be torn up, is necessary. At a wide street, however, where extremely long gate arms are required, the strain on the overhead wires is too great to operate the gate against hard winds, and in that case a "live" post is put in at the far side of the street, and pipe connections are laid, preferably between tracks, so as to avoid tearing up the pavement.

To give warning when gates are being lowered there is usually a bell on the gate arm, operated by a ratchet, and at much-traveled crossings a bell or gong is frequently placed on the tower. For use at street crossings where gates are located one or more blocks from the tower, or at one or more crossings where gates or flagmen are not required, but where it is nevertheless desirable to give a signal, the Bogue & Mills system includes a pneumatic or distant gong, which is operated by air pressure from the tower, connection being had by means of ⅜-in. pipe.

The foundation of a gate post usually consists of pieces of sawed ties halved together and buried in the ground so that the upper surface will come level with or a little lower than the sidewalk. In some cases, however, as where extra long arms are used, or where the hight at which the post must stand will not permit the foundation to be laid deep enough, an anchor tie is buried 3 or 4 ft. deep, with long bolts to secure the foundation. The principal trouble with gate operation is the freezing of the underground connections in winter. The difficulty arises from two sources —surface water and water of condensation. Surface water can be kept out by properly laying and connecting the pipes, or by substantial connections with the sewers in case the connections are run through conduits, without pipes. There is usually less trouble with pneumatic gates than with others in this respect, simply because the pipes must be made air tight or the gates will not work. The difficulty with water of condensation can be overcome by using pipes large enough to obtain a proper circulation of air. Authorities recommend nothing smaller than 1¼-in. pipe for wire or rod connections. To guard a gate post from wagon hubs where teams turn a corner, a piece of old rail may be planted for a fender, being set to lean toward the post, in position to keep the wheels at a safe distance.

It is practicable to operate all the gate arms at a crossing with a single lever or pump, but from the fact that it is frequently necessary to hold the gates open in front of a team while closing them behind to prevent other teams from coming on the crossing, the arrangement of operating the arms on each side of the track separately is preferable. With pneumatic gates there is one lever but a separate set of pipes and valves for each pair of gates. With lever gates there is a separate lever for each pair of gates. With the "Standard" gate it is arranged to lock both levers together whenever it is desired to operate all the arms simultaneously. This is done with the latch, and if independent movement is desired at any time the levers can be immediately released. To economize in expense of attendance crossing gates are sometimes operated from an interlocking tower in the vicinity, and the gates at two widely separated highway crossings are frequently operated from one position. The tower is sometimes located midway between the crossings, and sometimes at one of them. Either lever or pneumatic gates may be operated in this way, the distance from gates to tower being sometimes as far as 800 ft. Another idea in highway crossing protection that has been put in practice to some extent is the interlocking of two sets of gates, one set working across the street and the other across the railroad. Such an installation is particularly desirable where the steam railroad is crossed by a street railway, as then the protection of the crossing is in the hands of the railroad company. The gates are so interconnected that one set is always down while the other set is up, so that either the steam railroad or the street travel is blocked at all times. The prospect of being reported for tardiness in clearing the steam road for an approaching train should also be an incentive for the gateman to attend to the gates promptly. At crossings with street railways there should be derails or stop blocks in the street car tracks at a safe distance from the crossing and interlocked with the gates, for street cars have frequently been known to run into crossing gates and break them down.

It is not supposed that arm gates will absolutely stop travel over a crossing. They warn people that a train is about to pass, and this is supposed to be sufficient for the safety of the public and a reasonable fulfillment of the duty of the railroad company. Nevertheless accidents sometimes occur when the gates are down, for pedestrians are much in the habit of stooping under the arms and crossing the track in front of approaching trains. Danger of accident is greatest where there are yard tracks to cross or two or more tracks of any kind, for there are people who will thoughtlessly venture upon one of the tracks while a train is passing on another, and if a second train happens to be approaching, the sound of it is not liable to be distinctly heard. To a small extent gates are built to completely obstruct the street and sidewalks, breast high. At a number of crossings on the Long Island R. R., largely used by children going to and from school, screens are hung from ordinary gate arms to reach nearly to the ground. When the arms are raised these screens fold up out of the way. Hoisting gates on the portcullis idea are also used on a few railroads. Gates of this type on the Long Island R. R. consist of a light truss with $3\frac{1}{2}$x$4\frac{1}{2}$-in. chords (in four pieces), vertical bolts and $\frac{3}{4}$-in. iron pipe diagonals. The truss is 65 ft. 8 ins. long and 3 ft. 8 ins. high, and reaches within 12 ins. of the ground. It is carried by a braced bent (5x8-in. posts, with 3x6-in. braces) 10 ft. wide and 29 ft. high, over the sidewalk on each side of the street. At the top these bents are united by light trusses across the street and across the (two) tracks. The gate is counterbalanced and is hoisted by means of a shaft and pulley at the top of the bent, at each end. The gates on both sides of the track are operated from one crank, all the hoisting pulleys being turned by means of shafting and bevel gears.

185. High Speed.—High speed, which signifies higher speed, is a favorite topic for discussion at railway club meetings and in the daily newspapers, and of course the track comes in for its share of attention.

Properly considered, however, the question of increased speed, in a general sense, is more appropriately discussed by the financiers of railroads than by officials or employees concerned only with the operating or maintenance departments; for primarily the question of high speed is a financial one. Occasionally a writer will approach the subject with the apparent understanding that a problem is at hand the solution of which involves matters none other than the evolution of track construction and car equipment capable of accomplishing the end sought, when really the possibilities of train speeds depend a great deal more upon financial resources than upon mechanical or engineering achievements. It is no rash statement to say that as soon as people are willing to pay what it costs they can ride as fast as they please; at any rate, such will answer for the general statement of the case. In writing on this subject I lay no claims to gifts of prophecy, and there is no intention to suggest what might be the limiting speed of railway trains. It is certain that train speeds have for some years been increasing, but the increase has been gradual, and will likely continue so to be. The time is past when a speed of 60 miles per hour (while running) is considered wonderful or even noteworthy. Scheduled trains are making upwards of 50 miles per hour, average speed, including stops, over distances of several hundred miles. It is no uncommon event to attain an average speed of 80 miles per hour on a run of considerable length on some of our best roads, and higher speeds are recorded of test runs, at a spurt. For business purposes, however, it will be looking sufficiently far ahead during the early part of this century to consider schedule speed of 60 miles per hour, including stops, or a running speed of 80 miles per hour, as "high speed." Not until we actually get to carrying passengers over the country at that rate, on regular schedules, will it be timely to concern ourselves about average speeds of 80 and 100 miles per hour.

In the engineering field high speed is first of all a question of rolling stock, and secondly one of track. It would seem that a very important improvement of rolling stock would be some means to increase the effect of the brakes at high speed. A considerable increase of speed beyond present attainments in service, without a corresponding improvement of the braking equipment, would make it necessary to place signals farther from the danger point than is now required in standard practice. Improvement in braking apparatus for high speed would therefore work an economy in two ways. Another improvement in rolling stock which would conduce also to high-speed requirements would be an increase in the diameter of car wheels. Such increase, however, would set the car bodies higher, and unless the gage of the track was widened correspondingly, it would tend to make the cars top-heavy, and too responsive to rough surface in the track. Any proposition to change the gage, however, would be so revolutionary that it is not likely to be seriously considered, so that some sacrifices in other directions must be expected.

The improvements in track necessary to meet the requirements of high speed can be carried out on lines of practice already settled. In this field important conditions in any case must be smooth surface and alignment, which are merely questions of expense. Improvements which will involve change to the most extent will be the abolishment of grade crossings with highways, wherever practicable; the fencing of the right of way in more substantial manner than obtains in ordinary practice, and, in general, a more careful regard for conditions external to the track. High speed will mean the extensive installation of block signals, and interlocking apparatus at all grade crossings; the elimination of facing switches, as far as possible, and the interlocking of such switches with distant signals, where they must be retained; bridge floors should be solid and ballasted; and, drawing conclusions from the best results now attained, separate tracks for passenger and freight trains will be desirable, if not entirely essential. Still further, it is not to be overlooked that the tracks should receive close inspection at frequent intervals, which means that on at least some lines there would have to be a restoration of the track-walker. The limit of curvature for sustained high speeds will necessarily have to be small—down to 1 deg., say, for 80 miles per hour and somewhere in the neighborhood of ½ deg., and few curves at that, when we get to the point of preparing for speeds approximating 100 miles per hour. The curves will necessarily have to be elevated for the highest speed, which will require the spiraling of their ends. It will be desirable, although not entirely essential, to have unbroken rails at the turnouts, avoiding the use of frogs of the style now in ordinary service if a substitute can be found which will be safer for the main line, even though it may not answer so satisfactorily in every respect for train movements through the turnout. Some switch of the Wharton type is undoubtedly safer for main-line trains than the point switch.

During the fall of 1903 some unprecedented speeds were made on the Marienfelde-Zossen military line, in Germany, which aroused a world-wide sensation, and the particulars of the track construction and of the rolling stock are interesting in the present connection. The road was 14¼ miles long, nearly level and mostly straight, there being one curve of 52½ minutes (radius 6562 ft.) near one end. The track was laid with 84½-lb. rails, generally 39.37 ft. long, on fir ties, 18 to the rail length, with tie plates; 6-bolt angle-bar splices 31½ ins. long, with vertical flanges hanging 1½ ins. below base of rail, between joint ties, but some of the joints were of the lap type, as illustrated in Fig. 17, with a lap 9¼ ins. long. The ballast was broken stone. On 10½ miles of the line guard rails were laid inside the traffic rails, to a flangeway of 1.97 ins. These were ordinary T-rails laid on side, with the base (4⅛ ins. wide) presented for the service side of the guard, the upper edge coming 1¾ ins. above the top of the traction rail. They were supported upon cast iron chairs lag-screwed to the ties. With the exception of these guard rails on part of the line (which were found to be an unnecessary precaution), the track was, as thus to be seen, only of ordinary construction. There were two electric cars, one being used in each of the many experiments. Each car was 72 ft. long, mounted on two 6-wheel trucks, wheels 49.2 ins. diam.; wheel base of truck 16.4 ft. long; each truck equipped with two 250.-h. p. motors, on the outside axles, and air brakes, with brake shoes on both sides of all wheels; total weight of car 101½ tons. As the experiments continued the speeds were gradually increased until trips were made repeatedly at 105 to 110 miles per hour, or the whole distance each way in 8 minutes. The energy consumed in driving the car at such speeds was about 1600 horse power, and stops were made in 6560 ft. from the point where brakes were applied. On Oct. 23 one of the cars attained a speed of 128½ miles per hour, and on Oct. 28 the other car was run at the tremendous speed of 130½ miles per hour.

CHAPTER XII.

ORGANIZATION.

186.—In order to fully comprehend the relative importance of the track department in railroading it is essential that a just conception be formed of the magnitude of the railway industry in this country, the mileage of track, the cost of its construction and the annual expense of its maintenance. The total number of railroads (corporations) in the United States is between 2000 and 2100. As classified according to organization for operation, however, the total number of "operating" roads is a little upwards of 1000, of which about 800 are classed as "independent" roads and about 200 as "subsidiary" roads. The total length of railroad in the early part of 1904 was 210,000 miles, and this is being increased 3000 to 6000 miles each year. The total length of track, however, was about 289,000 miles, including, in round numbers, 17,000 miles of second, third and fourth tracks and 62,000 miles of yard tracks and side-tracks. For a proper investigation of the subject, however, it is necessary to fall back upon the latest available classified statistics, as contained in the report of the Interstate Commerce Commission for the year ending June 30, 1902. The total length of railroad on that date was 202,472 miles, and the total length of track 276,513 miles, which included 15,820 miles of second, third and fourth tracks and 58,221 miles of yard tracks and side-tracks. It is necessary to bear in mind, however, that the length of railroad covered by the reports made to the commission, and used as a basis for the statistics which follow, was 200,154 miles.

The total cost of building and equipping 187,442 miles of this railroad was 10,658 millions of dollars, of which amount the cost of road was 10,021 million dollars and the cost of equipment 637 million dollars. Complete balance-sheet statements were not obtained of all the mileage of road reported, but on the same basis the cost of the railroads in completed condition, with their equipments and other property, must have been not far from 11,500 million or 11½ billion dollars. From the official figures the cost of the road itself was $53,400 per mile of line, from which it might be inferred that the cost per mile of track was about $40,000, which includes, of course, the cost of roadbed and structures. The total operating expenses of the 200,154 miles of railroad reported for the year named was $1,116,248,000, of which amount the cost of maintaining track and structures was $248,381,000, and the cost of maintaining equipment, including all rolling stock and shops, $213,380,000. The cost of maintaining the track alone was $174,826,000; the cost of repairs and renewals of bridges and culverts, $28,888,000; the cost of repairing and renewing fences, road crossings, signs and cattle guards, $6,968,000; and the cost of repairing and renewing buildings and fixtures, $28,552,000. The total number of employees on all the railroads reported for the year named was 1,189,315, of whom 316,775 were trackmen, 35,700 being section foremen and 281,075 other trackmen; 227,442 were engaged as carpenters, machinists and other shopmen; 224,422 as trainmen; 9855 as general and other officers; 176,481 as general office clerks, station agents and other station men; and 233,360 as switchmen, flagmen, watchmen, telegraph operators and all other employees. It is thus seen that trackmen are by far the most numerous class of railway employees.

A review of the figures above quoted discloses the following facts: The cost of the track, roadbed and structures constitutes about 94 per cent of the entire cost of all railroad property. The expense of maintaining the track alone for the year 1902 was $874 per mile of line or about $644 per mile of track. Track maintenance costs about 15 per cent of all operating expenses of railways and is equaled by the maintenance expenses of but one other department—the expense of maintaining the equipment. The number of employees engaged in track maintenance constitutes 26.7 per cent, or more than one fourth, of the whole number of railway employees. The proper organization of the labor engaged in this department is therefore a matter of much consequence.

At the labor end the organization of employees for the work of the track department differs but little on the various railways throughout the country. On all roads the unit of organization is the section crew, which operates over, and looks after, a few miles of track, the responsible head being a section foreman or boss. Over each division or subdivision of 50 to 150 miles of road is placed an official generally known as "roadmaster," but in less numerous instances he is called a "supervisor." In exceptional cases the length of road in his charge may exceed or fall short of these limits. To this official all the section foremen are accountable, either directly, or indirectly through one or more assistant roadmasters or supervisors, the latter title being equivalent, on some roads, to that of assistant roadmaster on other roads. Thus far the arrangement may be considered pretty general throughout the United States. Likened to a military organization the roadmaster might be considered the lowest commissioned officer holding direct command—the captain, with his assistant roadmasters or supervisors as lieutenants. The section foreman would be a non-commissioned officer, and the crew the set of four.

It is in the arrangement of the positions above that of roadmaster that railroads differ in their organization of the track department. Logically considered, railway operation involves the maintenance of three separate and distinct lines of work, namely, that pertaining to roadbed, track and structures, or the fixed property of the company, properly termed engineering; that pertaining to rolling stock and the repair shops therefor, commonly recognized as the property in charge of the mechanical department; and that pertaining to the movement of trains and the handling of traffic, commonly understood as the work of the transportation department. The most common organization of the working forces of these three departments is what is known as the division system, the heads of the three departments reporting directly to the division superintendent, who reports to a general superintendent or general manager, so that in the distinct lines of work, as outlined, the separate departments are carried no higher than the division superintendent. This arrangement virtually makes the superintendent the general manager of his division. In this system it is usually the case that the responsibility of maintaining track and structures is divided between a roadmaster, for the track, and a master carpenter or superintendent of bridges and buildings, who has charge of structures. Quite frequently, however, the charge of both track and structures is combined with one official, who is called a supervisor of track and bridges, or is known by some other convenient title. Such doubling up of responsibility is more commonly the case on small roads or on roads where the bridge work is comparatively unimportant. On some roads where the signaling and interlocking work assumes importance there is a third division of responsibility in the maintenance-of-way department, whereby there is a signal engineer, or a foreman, supervisor or inspector of signals, reporting independently of the roadmaster or superintendent of bridges and buildings, to the division superintendent. In some cases, however, but less extensively than in former years, the maintenance of the signaling and interlocking equipments and their operation are in charge of the division roadmasters. On the Chicago & Eastern Illinois R. R. there is a foreman of signals, reporting to the superintendent of bridges and buildings.

On perhaps the majority of roads where the division system of organization is in force the name "engineering" is not associated with the maintenance of track and structures, as in that case the engineering department is usually limited, in its duties and responsibilities, to new construction of track, bridges and buildings, relocation, and work involving change of some sort, being represented on each division by an "assistant" or "division" or "resident" engineer, accountable to the division superintendent, perhaps in a nominal way, but reporting directly to the chief engineer, from whom he receives his instructions. Whatever duties he or the chief engineer may have in connection with the maintenance of the track are usually in a consulting capacity, and more frequently in relation to standard plans and specifications, surveys of the right of way, etc. The head of the mechanical department of the division is the master mechanic, but in this department, also, the responsibility is frequently divided between the master mechanic and a master car builder. The head of the transportation department of the division is the trainmaster, with his yardmaster, train dispatchers, etc.

Examples of roads on which the division system of organization is in force are so numerous that it is hardly necessary to designate, but the Chicago, Burlington & Quincy, the Atchison, Topeka & Santa Fe, the New York, New Haven & Hartford, the Erie, the Northern Pacific and the Wabash roads may be referred to. On the various roads where this system is in vogue the relative standing of the roadmaster is about the same, but the scope of his authority varies to some extent. Thus, for instance, on some roads, the roadmasters have an assistant engineer or surveyor, with a small party. On the New York, New Haven & Hartford R. R. the maintenance of track on each division is in charge of a roadmaster, the maintenance of bridges, turntables, coaling and water stations under a supervisor, and the maintenance of signals and interlocking under a signal engineer, all three of whom report to the division superintendent. The superintendent of buildings, however, who has charge of the carpenters, masons and painters, reports direct to the general manager.

Another distinct system of organization for railway operation is the department system, in which the three distinct lines of work, namely, the engineering, the work pertaining to rolling stock, and to transportation, are carried up separately to department officers reporting to the general superintendent or general manager. Thus, in the track department the division roadmaster may report to an engineer of maintenance of way, a general roadmaster or superintendent of tracks, who reports directly to the chief engineer, if the engineering department has charge of track maintenance, or to the general superintendent or general manager, where maintenance work and construction are in separate departments. Division master mechanics report to the superintendent of motive power, who reports to the general manager; and the division officer of transportation reports to the superintendent of transportation, who also reports to the general manager.

There are but comparatively few roads operated on the department system pure and simple. One of these is the Michigan Central R. R. On that road the chief engineer has full charge of both the construction the maintenance of all the fixed property, and the reports from beginning to end reach him by a direct process; that is, independently of any division officer outside of his own department. The division roadmasters report to division engineers, who report to the assistant chief engineer. Under the division roadmasters there are assistant roadmasters over sub-divisions of about 100 miles each. On each division there are masons, carpenters and painters reporting to the division foremen of buildings and water supply, who reports to the superintendent of buildings and water supply, who reports to the chief engineer. There are division foremen of bridges and assistant bridge engineers, reporting to the bridge engineer, who reports to the chief engineer. Inspectors of signals and interlocking report to the signal engineer, who reports direct to the chief engineer. The assistant chief engineer, who receives the reports of the division engineers and performs other work usually connected with that title, reports direct to the chief engineer. It is thus seen that immediately under the chief engineer there are four subordinate officers on apparently the same footing, namely, the bridge engineer, the superintendent of buildings and water supply, the signal engineer, and the assistant chief engineer, who are in direct charge of all the maintenance-of-way work and construction on the several divisions. The division superintendents have charge principally of train operation.

On the Lake Shore & Michigan Southern Ry. the engineering department has direct charge of the maintenance of way, the division roadmasters reporting to the principal assistant engineer (of the chief engineer's staff) independently of the division superintendents. Formerly the New York Central & Hudson River R. R. was another example of a road conducted on the department system, the engineering department having charge of all construction and maintenance of the fixed property. That organization, although changed, is still of interest in the present connection. On maintenance of way work on each division there was a supervisor of track, in charge of the track forces, wrecking gangs and steam shovel forces; a supervisor of bridges, in charge of iron men, masons, pile-driver crews, bridge carpenters and bridge painters; a supervisor of buildings, in charge of carpenters, painters, mechanical foremen, scale men, water supply and electrical mechanics, etc.; and a supervisor of signals, in charge of the signal maintenance forces. These officials, together with the assistant engineer, reported to the division engineer, who in turn reported through various staff officers, to the chief engineer. The heavy construction work was handled by the resident engineers on each division, reporting through the principal assistant engineers to the chief engineer. The chief engineer had on his staff certain assistant engineers who handled special work assigned to them from time to time, such as mechanical questions, bridge designs, track problems, etc. Besides the assistant chief engineer and the two principal assistant engineers there was an engineer of track, an engineer of signals, and an engineer of structures. The change which took place in 1903 was the appointment of an engineer of maintenance of way, reporting direct to the general superintendent. The duties of this office cover the execution of the standard plans and the charge of all current maintenance of track, bridges, buildings and signals, under the direction of the general superintendent. The office of engineer of track was abolished. The chief engineer prepares the standard plans and has charge of the construction work.

It has come to be quite largely the practice to place the maintenance of way work in charge of men of engineering training, with engineering titles, but in most cases the construction and maintenance branches of engineering are conducted separately and independently. Some roads whereon this is the case are organized on the division system pure and simple. Thus, on each division of the Ohio (grand) division of the Erie R. R. there is a track supervisor and a master carpenter, reporting to a division engineer, who reports to the division superintendent, who reports to the general superintendent, who reports to the general manager, who reports to the second vice-president on an equal footing with the chief engineer. The general superintendent is assisted by an "assistant chief engineer." On quite a number of roads where division engineers have immediate charge of the maintenance of way work there is nominally, at least, a maintenance of way department, under an engineer of maintenance of way, general roadmaster or superintendent of tracks, but usually the division principle of control prevails. That is, the line of authority passes through the division superintendent, in whom all the reports and business of the lower officials of the various departments are first drawn to a focus, and from whom the digest is dispersed to the various department officers above him. In other words, the reports of the division officer in each department reach the superior officer in that department second hand. In such cases the organization might be recognized as semi-departmental or as a combination of the division and department systems. On some roads the engineer of maintenance of way or general roadmaster is in authority, and receives the reports of the division superintendents respecting maintenance matters, while on other roads he acts only in an advisory capacity as an assistant to the general superintendent or the general manager. In the one case the departmental principle predominates and in the other the divisional principle. And again, some roads are organized on a compromise basis, part of the maintenance of way officers reporting to higher authority through the division superintendents and others reporting to the engineer of maintenance of way or to the chief engineer direct. The title of general roadmaster, by the way, is, on some roads, equivalent to that of chief engineer, and carries all the duties and authority of that office. Such is the case with the Florida East Coast Ry. and the Chicago & Western Indiana R. R.

On the Pennsylvania R. R. the chief engineer, who reports to the second vice-president, has general charge of the construction work, until it is completed, when it is turned over to the maintenance-of-way department, in charge of the general manager, who is assisted by the chief engineer of maintenance of way. On each division there are supervisors having charge of 25 miles of road, to whom the section foremen report. These supervisors and a master carpenter report to a division engineer, who is called an "assistant engineer," who reports to the division superintendent, who reports to the general superintendent (of the grand division), who is assisted by a "principal assistant engineer." The principal assistant engineer, on the staff of each general supt., and the chief engineer of maintenance of way, on the staff of the general manager, do not have direct personal control over the engineering forces of the road, but handle the maintenance of way department through their respective superior officers, who rely upon them to watch all the details and keep matters straight. The following extracts from the organization rules of the road show a little more in detail the duties of the heads of the two engineering departments: "The chief engineer shall, under the direction of the second vice-president, have charge of all engineering and construction work upon the railroads owned, operated or controlled by the company east of Pittsburg and Erie, and be responsible for the proper preparation of plans, specifications and estimates connected therewith; and also for the preparation of plans and specifications for all bridges and other important structures. He shall keep in his office a detailed record of the cost of all new work chargeable to construction account; prepare and certify to the correctness of the charges therefor, and forward to the proper officer for approval and payment the necessary bills and pay rolls. He shall keep an account and have charge of the distribution of steel rails for construction and renewals. He shall perform such other duties as may be assigned to him by the second vice-president, the president, or the board. . . . . The chief engineer of maintenance of way shall have general supervision of the maintenance of way department, and shall assist the general manager in all matters pertaining thereto and keep the general manager advised of the condition thereof. He shall be responsible for the preparation of maintenance of way plans, which, after approval by the general manager, shall become standard. He shall be aided by an engineer of maintenance of way. . . . The engineer of maintenance of way shall, under the direction of the chief engineer of maintenance of way and of the general manager, have direct charge and control of the maintenance of way department in so far as may be necessary to insure the efficiency of the department and adherence to the standards of the company. He shall prepare, for the approval of the chief engineer of maintenance of way and of the general manager, all maintenance of way plans. He shall furnish the principal assistant engineers with copies of all standard drawings, and shall give them such instructions as may be required to insure adherence thereto. He shall, with the approval of the chief engineer of maintenance of way, make such suggestions to the general superintendents as may promote the efficiency and economy of the service. It shall be his duty to thoroughly inspect in person all bridges and other structures, and make report thereon to the chief engineer of maintenance of way." The engineer of maintenance of way is assisted by an engineer of signals. On some of the grand divisions the principal assistant engineer is assisted by an assistant engineer; and on some of the divisions there are assistant supervisors.

The organization of the Pennsylvania Lines West of Pittsburg is similar to that of the "Lines East." The section foremen report to a supervisor, the supervisor to an "engineer of maintenance of way," the engineer of maintenance of way to the division superintendent, and the latter reports to the general superintendent of the grand division. On the staff of the general manager there is a "chief engineer of maintenance of way," who communicates with the general manager, the general superintendent and division superintendents in matters connected with the maintenance of way department. The chief engineer of maintenance of way is responsible for the preparation of maintenance of way plans and standards, subject to the approval of the general manager, and he has direct supervision of construction work on completed lines, preparing plans and estimates for the same.

On the Southern Pacific road the chief engineer, who reports to the president, has charge of construction and important changes, while on each grand division of the road, east and west of El Paso, Tex. (the Atlantic and Pacific systems), there is an engineer of maintenance of way reporting to the general manager of the Southern Pacific Co. in matters relating to standards, and to the manager of his "system" regarding other matters. The engineer of maintenance of way has charge of track, bridges, buildings, water supply, coaling stations, turntables, signals and interlocking. On the Atlantic system each superintendent has direct jurisdiction over the mechanical, maintenance of way, train and station service on divisions varying from 300 to 500 miles. He has general charge of the maintenance of his division, reporting to the engineer of maintenance of way in all matters relating to track, bridges, structures, water service and signals. He is assisted by a resident engineer, who has direct charge of these matters with the exception of signals. Each resident engineer is assisted by a number of roadmasters, depending upon the length of the division, and by a superintendent of bridges and buildings. The engineer of maintenance of way is assisted by an assistant engineer and by an assistant engineer of signals. On the Pacific system of the road the section, bridge, and building foremen report to roadmasters, who report to resident engineers, who report to division superintendents, who report to the engineer of maintenance of way regarding maintenance. The signal department is headed by a signal engineer, who reports to the engineer of maintenance of way.

With the Lehigh Valley R. R. there is on each division a supervisor (of track) and a master carpenter (or foreman of bridges and buildings), both reporting to a division engineer, who reports to the division superintendent, who in turn reports, on matters relating to maintenance, to the engineer of maintenance of way, who reports to the general superintendent. On this road the general superintendent has duties similar to those of a general manager on other roads. The chief engineer, who has charge of all construction work, bridge renewals, special heavy structural work and general engineering investigations, reports to the general superintendent. There is a bridge engineer reporting direct to the chief engineer, and a signal engineer reporting direct to the engineer of maintenance of way.

The organization of the Illinois Central R. R. is a combination of the division and department systems and is more complicated than any of the foregoing. The immediate assistants of the president are a vice-president, who has charge of the finances; a second vice-president, in charge of operation and traffic; a board of pensions, various officers constituting the legal department, and a secretary. The general manager receives the reports of the assistant general manager, general superintendent of transportation, assistant general superintendent, superintendent of telegraph, chief surgeon, chief claim agent and chief special agent. The assistant general manager receives the reports of the superintendent of machinery, chief engineer, consulting engineer and chief engineer of construction. The maintenance of way proper is in charge of the division superintendents, who receive the reports of the roadmasters, station agents, trainmasters and master mechanics, although the last named report on some matters direct to the superintendent of machinery. Road supervisors having charge of about 100 miles of track, supervisors of bridges and buildings having charge of the ordinary repairs of bridges and buildings, and waterworks foremen report to roadmasters of divisions 350 to 500 miles in length; and, as above stated, these roadmasters report to the division superintendents. North of the Ohio River the division superintendents report to the chief engineer in matters relating to construction and maintenance of way, to the superintendent of machinery on machinery matters and to the general manager in matters pertaining to transportation and other affairs; south of the Ohio river the division superintendents report to the same heads through an assistant general superintendent. It will be noticed that the position of supervisor on this road corresponds to that of roadmaster on most other roads, and the position of "roadmaster" to that of division engineer. On this road special bridge construction and renewal of bridges are in charge of the superintendent of bridges, and the special construction and renewal of large buildings in charge of a master carpenter, both of whom report to the engineer of bridges and buildings, who reports to the chief engineer. Signals and interlocking are in charge of a signal engineer, who reports direct to the chief engineer. Other officers reporting direct to the chief engineer are the architect, the general foreman of waterworks and the supervisor of scales. In some matters the master carpenter reports direct to the chief engineer instead of through the engineer of bridges and buildings.

The classification of systems of organization here presented covers practice only in a general way. The details of the various organizations in existence among the different roads are almost too numerous to admit of ready generalization. On some roads both the division and department systems are in vogue on the different grand divisions, while on others, as already seen, there is a combination of the two systems. On some roads there is a semblance of the department system where, for instance, the office of the general roadmaster is made an advisory one, the division roadmasters reporting to the division superintendents, who consult the general roadmaster regarding standard plans, methods, etc., but to whom they do not report the work and expenses of the department.

It is hardly worth while to inquire for reasons explaining the adoption of this or that system of conducting maintenance work. Probably the best explanation of the differences existing is that different men in official capacities have different views regarding ways of carrying on business. The fact that some general officers prefer to be in close touch with details, while others assume to select subordinates who are competent to shoulder such responsibility, explains a great many differences. Apparently there are good arguments for either the division or the department system, and there is evidence to show that either can be conducted economically and smoothly. There could therefore be but little profit in discussing the relative advantages or disadvantages of the various organizations in vogue. The important matter for consideration is that there shall be adequate responsibility for the safe running of the trains and for the economy of track maintenance; and that in placing this responsibility it should be equitably and consistently distributed among capable and reliable heads from the top to the bottom of the list. But such is an old song, and professedly is never departed from in making appointments; and so we arrive at the starting point. So far as track maintenance is concerned, it is my opinion that it matters but little how the higher offices are arranged or classified, so long as the man who is held responsible for each division or each hundred miles, more or less, of the road, is reliable, understands his business, and is so supported that he can carry it out—be he called roadmaster, division engineer, supervisor or what not. The ball starts rolling with the section foremen. Unless the roadmaster (or equivalent officer) be competent to select good foremen he cannot hope to succeed, and no number of wise men in the higher positions—either division superintendents or engineers—can make amends for deficiencies in the office of roadmaster. On the other hand a competent roadmaster can do good work whether the officials over him are competent in his line or not, providing he is not interfered with. If at this juncture a suggestion should follow I might venture to say that over the head of the roadmaster there should be but few officials in direct authority—one might almost say the fewer the better, because his position is one of great responsibility and his relations with the chief of his department should be as direct as may be possible, considering the size of the road. For the successful conduct of track maintenance the roadmaster must be a man who can be depended upon, but to interpose a multiplicity of routine processes between him and the source of issue is to encumber his work, discount his judgment and subordinate his position. More than upon any one else the responsibility for the physical condition of the track falls upon the roadmaster. He must judge of the fitness of men to take charge of sections of the property, to look after it and to direct the labor to be done upon it, and he must be responsible for the discipline of these forces.

187. The Roadmaster.—The roadmaster is referred to so many times in connection with various kinds of regular and emergency work and supervision that a list of all his duties in detail is hardly necessary in this place. In a general way, however, we may look at some methods for the government of his work. The greater portion of a roadmaster's time should not be spent in the office—he should be an inspector rather than a bookkeeper. While he should keep well enough posted on the important statistics relating to his track to have the run of things, the clerical force of his office should be sufficient for routine matters and so well instructed that he need give to such affairs only a general supervision. The roadmaster should manage to escape the bondage of office routine. No executive officer can exercise the best of his ability if the most of his time is consumed in clerical duties of a recurring nature. Neither should he make himself too conspicuous for his presence at the rear end of the passenger trains. The manner in which the foremen and men on some roads watch the movements of "the big boss" has become proverbial. The trackmen meeting from different sections seldom pass the time of day without referring to the time and place when the roadmaster was last seen. It is customary to either enquire or report whether he is "up the line" or "down the line;" and should he ride past without their knowledge, or fail to appear on certain days, there is then all sorts of speculation as to what is going to happen. While with the right kind of men the habits of the roadmaster in his calls should be of little or no concern, yet where there are some of the "watchful" kind it is wholesome practice for the roadmaster to make visits at any and all times, unannounced and unexpected.

On the principle above stated roadmasters should spend a large part of their time at inspection of the track and in personal contact with the section crews. Maintenance of way officials should lay stress upon daily, rather than annual, inspection of track. The roadmaster who gets nothing more than a glance at things occasionally, as he rides by on the trains, will, upon closer inspection at the end of the year, or even after but a few weeks, usually find many things which should have received his attention long before. He should have accurate knowledge of the state of affairs at all times, and this can be had only by frequent inspection. The many forms of hand and machine-propelled inspection cars make it convenient for the roadmaster to do this. It is wasteful of a good deal of time to encourage section foremen in the habit of hanging around or working near stations purposely to get a chance to talk with the roadmaster while the train is stopping. In such cases it usually happens that the foreman gets about half the information he wants by the time the train starts, and then the conversation is cut short. Information regarding the work at any point is best given or received on the ground; hence the importance to the roadmaster of traveling independently of the trains. It is also a good plan to do a good deal of walking, especially in the summer time. It is well enough to make use of the hand car and section crew, or part of the crew, when time is limited and it is desired to reach some certain point, but for a close observation of things the best opportunity is to be had by walking. It is important for roadmasters to frequently investigate the wear of material, and to discuss the same with their foremen, and this can best be done by walking over at least parts of the sections where there is occasion for making observations. The best method of inspecting a section with the foreman is to walk over the track with him alone. In this way there is time for discussing matters as they come to view, and opportunity for correcting the foreman in any mistakes or wrong methods, at a time when he will not be embarrassed by the presence of his crew. It works harm to correct a foreman within the hearing of his men. Even a slight disapproval of his work subjects him to chagrin and tends to lessen the respect which the men have for his authority. At times, when it is found that the work is not being done satisfactorily, some roadmasters will go so far as to take the work out of the foreman's hands and issue orders to the men direct. For the sake of discipline such practice should be avoided, as far as possible, for, if occasion requires, better results can usually be had by calling the foreman aside and instructing him privily.

Many railways require their roadmasters to make close inspection of their divisions at least once each month, and some roads require it oftener. The rules of the Southern Pacific Co. require the roadmasters to "pass over the entire straight portion of their districts, either on foot or on velocipede cars, at least twice every month, and over that portion in canyons and in the mountains at least three times per month." This method of getting over the work is the most thorough, and instructions can be issued to the foremen on the ground more satisfactorily than by hastily written notes ("butterflies," the trackmen call them) flung from the rear of trains. On such visits the roadmaster should be in no hurry, but spend considerable time with each crew, so that he may observe and criticise methods of work. This is an important matter, and an attempt should be made to secure uniformity of the best methods of work among all the crews. In this way the roadmaster can get acquainted with the men, and they will come to know and understand him. By keeping his office informed as to his intended movements and making himself accessible to telegraph stations as far as possible, he can spend two or three days at a time out on the road. He should get so well acquainted along the track that he will feel at home wherever night overtakes him. The interests of any railroad company may be materially advanced by the larger personal acquaintance of some of its well disposed officers with the residents along the line. By suitable preparation for the unexpected, and proper understanding at headquarters, a roadmaster, even if out on the road when emergencies occur, can almost always handle things satisfactorily. While there is a work train engaged the roadmaster should aim to get around to it two or three times per week, or perhaps oftener, if the importance of the work so demands. To observe line and surface to every advantage he should occasionally make a trip over his division on the locomotive of a fast passenger train. At wrecks his presence is generally required.

The roadmaster must handle his men with decision and firmness, yet with a kind of firmness which conveys no impression of obstinacy. He should be capable of gentleness, where such treatment answers best. He must be prepared to meet emergencies promptly and effectively and without hesitation. His relations with his men must be such that they will respect not only his intelligence and his experience, but also his disposition and his character. He should be an accurate and thorough observer, unhesitating in correcting neglect and other defects in his foremen. He must be able to look ahead and plan his work and aspire to keep abreast of his work, and not let the work do the pushing. Roadmasters should not fall into the habit of giving specific orders to foremen every time it becomes necessary to take up routine work, such as tie renewals, cutting grass and weeds, mowing, cutting brush, etc. New foremen should be instructed concerning the proper season for the various kinds of ordinary track work, but the old foremen should be given to understand that such work must be taken up at about the proper time without specific orders. The care of looking closely after all such matters throws too much work upon the roadmaster and virtually relieves the foremen of that much responsibility for the condition of things under their charge. In case it is observed that a foreman has failed to do such work as might have been expected of him, it is more conducive to discipline to require from him an explanation than to forthwith order him to do it. The section foreman's position necessarily carries with it a good deal of responsibility, and this is the main thing to be impressed upon the foreman's mind. It cannot be done, however, if the roadmaster assumes to direct the ordinary work of the section.

The office work should be in charge of a clerk who has a liking for the work and to whom all routine matters can be left. He should be something more than a bookkeeper—a sort of private secretary, say, who understands so well the plans of his chief that he can answer the bulk of the correspondence on his own responsibility, leaving for the roadmaster's approval only such matters as require executive discretion. He should acquaint himself thoroughly with the track, especially concerning the physical characteristics along each section, and he should get acquainted with the men. In order to do this he should be given opportunity to make occasional trips out over the road, preferably in company with the roadmaster. The position is no mean one, for the services of a good clerk are invaluable to a roadmaster, and some discrimination is necessary in selecting a man with the qualifications necessary to fill it. A trackman possessing at least a common school education should be sought.

A roadmaster having charge of 100 miles or more of double track will usually need one or two assistants. Such assistant, sometimes known as assistant roadmaster and sometimes as supervisor, should be a man in whom the roadmaster can place entire confidence, and whom he can entrust to act in his own capacity when sent to look after special work, or who can act for him on his (the assistant's) own judgment if present where exigency demands decisive action without delay. One of such men will usually be needed around the work train most of the time, and, on many roads the assistant to the roadmaster is given charge of the work train. As a rule it is best not to have much authority come between the section foremen and the roadmaster, except where, as is the practice on some roads, supervisors, under the roadmaster, or under the official corresponding to roadmaster, are given regular charge of portions of the division. Of course special occasions will arise when circumstances will prevent misunderstanding, and it is in such particular lines that the assistant can be most useful, rather than by trying to oversee those ordinary affairs where even slight differences in judgment between him and the roadmaster are confusing to foremen. If, however, owing to a division of too great length, the need of an assistant consists in the multitude of regular track duties, rather than in lines of special work, it is well to set off a portion of the division to the assistant and give him full control as far as direct supervision is concerned. This plan works better than that by which two men conjointly try to supervise the whole division as to details; because the ordinary duties are of such nature as not to require a division of the supervisory authority. Where part of the division is in this way put under an assistant, the roadmaster may find in it such relief that while looking after the whole, yet paying special attention to the other end, he may be able to get along with one assistant.

The qualifications for the position of roadmaster are considered at some length under the heading "The Training of Roadmasters," § 206, Supplementary Notes.

188. Section Foremen.—The section foreman is employed to look after the safety of a piece of track of certain length and, with the help of a crew, to maintain it in good condition. He should therefore be reliable, honest, competent, and intelligent. No man, however able, should be placed in a position of trust or be allowed to retain it who cannot be relied upon. Some men are unreliable out of indifference or neglect, while others are so because they are dishonest; but as far as there is any dependence there can be no choice between the two. Much property is placed in the hands of the foremen, and the condition of the track and the economy of its maintenance rest largely upon their ability and judgment, but no less important to the same ends is integrity of character. In order to be reliable a man must be willing, or he may not be strong enough to carry out his professed motives. His first duty, above others, is to at all times satisfy himself that his track is safe for the passage of trains and, in case of doubt, to use all possible means to ascertain its condition and make it safe. This implies that he must be willing to go at all hours and in all kinds of weather to threatened points on his section whenever, in his most reasonable judgment, he thinks he might be needed there.

In order to be competent the foreman must necessarily have had considerable experience as a track laborer, and to have become so skillful at it that he is able to instruct others. The criterion by which some would judge of a man's fitness to take charge of a section would be his ability to lay a turnout or "switch," as trackmen usually call it. Somehow there seems to exist with trackmen pretty generally a sort of strange fancy that, connected with "putting in a switch," there is some hidden secret or trick of the trade, so to speak, which, if once discovered or mastered, opens up to one all the supposed arts of the trackman's craft, or about all there is concerning track that is worth knowing. It is hardly necessary to comment upon ill-conceived notions of this character. Suffice it to say that while some good trackmen who have never had opportunity for doing such work might be a little slow at the first turnout attempted, yet no man could be considered anything of a trackman who could not choose a fair location for a turnout and oversee the laying of it properly. And there are, too, some railroad surveyors who will fuss around the location of a turnout for a spur track as though it must be placed with mathematical precision, instead of proceeding with a view to choose favorable ground and place the headblock or frog with such relation to the joints as will reduce rail cutting to a minimum. And they will also set stakes for the curve of the turnout between headblock and frog, when a frog table gives all the necessary measurements for locating the different parts of the turnout and for properly curving the lead rail. Competent track foremen do not waste time on such matters. It is but stating what every experienced trackman knows, to say that there are scores of instances where foremen are called upon to use more judgment than is ordinarily required when laying frogs and switches. It is needless to attempt to give, even in a general way, an enumeration of the things in track work which a foreman should have knowledge of. The entire treatment of section work in the foregoing chapters relates only to practical details which foremen should know about. A fair amount of knowledge is essential, but proper judgment, which must be used with it, can come only from experience. Knowledge alone, in the sense of mere information, is not always a safe guide, for a certain amount of that can sometimes be picked up in a short time without learning the uses to which it may be put.

As for his intelligence or education, it goes without saying that every foreman should be able to express fairly well his thoughts in writing and to be able also to perform the fundamental calculations of arithmetic; but alas, how many are the instances where foremen are unable to measure up to these simple qualifications! Some can neither write nor cipher, nor read plain language understandingly, and must consequently seek assistance from the station agent or from some of their men; while others are so poor at ciphering that many a time book goes in filled out evenly opposite all the names, or with a full mark under each date worked, purposely to avoid multiplying fractions or picking them out of the table of wages, usually placed in the back of the time book. There are many people (and not all trackmen, either) able to read, to whom tabulated information is practically as difficult as hieroglyphics. Certainly, roadmasters are to blame for appointing such men to position.

Before any man is appointed foreman he should succeed in passing a thorough oral examination covering the principal duties he is to assume and the ordinary work of the section. Stress should be laid upon ascertaining his knowledge of the use of signals, and his judgment as to just what ought to be done in certain cases of emergency, such as broken rails, slides, washouts, etc. He should also, as part of his examination, be required to make out reports and fill out and make up a time book, from a given diary or memorandum of the daily work of a section crew for a month.

The best plan to follow in selecting section foremen is to look for promising men among the most competent track hands in the different crews, giving preference always to the men oldest in point of service. By consulting the old time books or pay rolls on file at the headquarters the roadmaster can ascertain who are the oldest men in the service without making his purpose known. These men should be specially sought out by the roadmaster, who should for a time observe closely their work and movements, with a view to determine in his own judgment the ability and fitness of each, before inquiring of his foreman. It frequently happens that an old and well deserving track laborer is purposely withheld from promotion out of jealousy or prejudice on the part of his foreman, or from a desire on the part of the latter to aid certain other of his friends. And then, too, some foremen are very cautious about allowing any opportunities for apprenticeship under them or of imparting information to their men, while other foremen have not the ability so to do. The roadmaster should, therefore, investigate for his own benefit and to his own satisfaction, and endeavor to fill vacancies by drawing from the rank and file in preference to hiring outsiders or men from another division.

A good way for the roadmaster to ascertain the qualifications of men as foremen is to have an apprentice crew work as a floating gang, under an expert foreman who is known to be a good and impartial judge of men, and whose disposition and characteristics are worthy of imitation. Such a floating gang is usually needed on most roads and the variety of work to which it is assigned furnishes an excellent school for prospective foremen. The aim of the foreman of this gang should be to hold up to the men a high standard of duty. He should constantly impress upon their minds the importance of economizing time and material and the necessity for thorough work and careful inspection. They should be required to familiarize themselves with the rules of the track department and the various adopted standards for roadbed sections, ditches, frog and switch construction, switch layouts, curve elevation, etc.; and they should, of course, acquire readiness in construction and repair work about switches and frogs. Wherever opportunity arises for comparison of different methods or standards of work the foreman should discuss with the men the advantages and the defects observable. When surfacing or lining track the men should be allowed to take their turn at sighting the rail, and they should have instruction and practice in making reports. This can be arranged by permitting each man to attend to the foreman's reports a month at a time. In time, therefore, good opportunity is afforded to observe the disposition and willingness of the individual men to learn to work for the company's interests. Into this crew the roadmaster may call those men whom he considers suitable candidates or those old hands who desire to make application. After working some time a man's fitness will show itself and, as new foremen are needed, men can be drawn from this crew in turn and given examination with a view to advancement, but some may have to be rejected without examination.

In order to test a candidate's ability for handling men he can be sent to take the place of some regular foreman who is absent on account of sickness or other cause, or he can be put in charge of a gang to do some special work, if necessity arises. In such ways as this there is opportunity to work the man in gradually and ascertain his qualifications. This plan places the roadmaster on an independent footing, for whenever it becomes necessary to make a change for the good of the service or when vacancies occur he has satisfactory men to put in charge. If the situation is otherwise he may often hesitate to make needed changes, out of fear that available substitutes may not do any better, or in cases of emergency he may be obliged to appoint men of doubtful qualifications. Incompetency that is not discovered until after a permanent appointment has been made often results in costly mistakes, and such failures have a demoralizing effect upon the service.

The system of recruiting foremen from among the section laborers stimulates the ambitious young men and puts a premium on faithful and efficient service. Inducement is then held out to those progressively inclined, and the company is able to retain a better class of labor than otherwise, so that the system is productive of good results in more ways than that of securing a desirable class of men for foremen. The system of training foremen in apprentice gangs is in force on a number of roads, and the results are generally satisfactory. For sake of example reference may be made to the Oregon Short Line R. R. On this road there is a training gang on each roadmaster's division, most of them being located at division terminals. The men for each of these gangs are employed by the roadmaster of the division, who selects young men seeking to make track work their occupation. A foreman of more than ordinary ability and intelligence is selected for the gang and the men are paid ordinary track laborer's wages. The roadmaster puts in a good deal of his spare time with these men. They are instructed in track surfacing and lining, laying switches and turnouts and in general track repairs. They are also taken out to assist at wrecks, washouts, etc., and in this way get a good general knowledge of all kinds of track work. A high official of this road has stated that some of the best foremen in the service have been trained in this way.

Another plan that is followed a good deal is to pick out the best man in each section crew and make him track-walker, and then when a foreman is needed promote him from the grade of track-walker. There is reason to doubt whether this plan is as satisfactory as that of the training gang, for the position of track-walker removes the man from active participation in track work, and he remains all the time on the "same old section." In the training gang the man has opportunity to see more kinds of work done than he is liable to find on any one section, and he sees the same kind of work done under a variety of conditions. He also comes in contact with a good many trackmen and gets in touch with their ideas, and the tendencies of such an experience are broadening. It is also to be remarked that there are many men well qualified in every way for track-walkers who have no capacity for handling a crew of laborers.

The importance of selecting good foremen cannot be overestimated. Aside from the roadmaster's own fitness it is the keynote of his success. The test of executive talent in any official is his ability to secure and retain the services of capable and willing men as his subordinates. This for the simple reason that good subordinates, when properly organized, can keep things moving. Many can doubtless call to mind what excellent reputations some men have built up for themselves on the skill and brains of other men, simply by dint of their executive ability, and nothing else; whereas other men of far greater resources and abilities, without competent subordinates, or by distrusting their subordinates, have tried to accomplish too much by their own efforts and have failed. In order to secure men of judgment for his subordinates an official, particularly when taking a new position, must sometimes resort to the weeding-out process. And then, again, any one is liable to be mistaken, at times, in judging of men, and some have not the moral courage to afterwards right the matter even though they see the mistake. It is an unpleasant duty to have to discharge a man for incompetency alone, especially if one is dealing with a man of character or with an old acquaintance; yet such must be done, at times, if an official is to do right by his position. The man least troubled in this respect is undoubtedly he who makes it an unvarying rule not to appoint intimate personal friends to position. Relevant to the same subject is another matter which should not escape attention, and that is the influence of race prejudice in the appointment of men to responsible positions. The policy which makes nationality the basis of eligibility in filling positions, particularly in a country like this, is short-sighted and weak. It is destructive of good feeling and it is bound to lower the standard of fitness for position. It is detrimental to discipline and gives to the favored class a certain conceit of themselves which is not promotive of industry. About the least one can say of any man who follows such a policy is that he is too narrow-minded to properly discharge the duties of roadmaster.

Foremen should be given authority to hire and discharge men. No man should be discharged, however, except for cause, or when forces have to be reduced. In the latter case it is customary, of course, to retain the oldest employees. A roadmaster should not be too willing to investigate every complaint coming from discharged men, still it is but fair that he should give earnest attention to those complaints when coming from old employees. A foreman should always be sure of his position when discharging an old employee for any cause, and if so, any fair-minded roadmaster will stand by him, and he need not fear investigation. A roadmaster cannot very well afford to override the authority of the foreman in such matters, or compel him to retain men in his employ whom he does not like: it is easier to discharge the foreman, when it comes to that. Another way out of a difficulty of this kind, if the roadmaster is satisfied with the merits of the "distasteful" employee's case, is to find opportunity to promote him.

In order to get along well with employees it is necessary to make careful discrimination in the selection of them. One discontented, refractory man will often spoil the discipline of a whole gang. The only thing to do with such men is to promptly discharge them. As soon as a foreman finds that a man is incompetent, unwilling or disposed to stir up mischief he is compromising matters by retaining him longer in service. If a man has worked in the same place a long while it is presumable that he is a worthy employee, and the foreman who discharges him necessarily places himself on the defensive. A foreman should not be upheld in discharging men because they refuse to board with him or because of any wrangling springing out of that or any other personal matter. Complaints of this nature will sometimes bear close investigation. It is certainly to a company's interest to know whether the chief business of any of its foremen is that of running the section or running a boarding house. In the same connection, foremen should not be permitted to use the services of their men as wood choppers, berry pickers, gardeners, or at other personal work, on the company's time. Neither should foremen be expected to present the roadmaster with turkeys each Thanksgiving or Christmas, or with a mess of fish occasionally. It is usually the case that such "offerings" are fully compensated for in one way or another, and by accepting such things the roadmaster places himself in a compromising attitude toward a strict enforcement of discipline.

The rules of most companies require that the foremen shall "engage in the work, personally," but it is well understood that they cannot always do this and at the same time properly oversee the work of their men. The question is sometimes raised, therefore, as to whether or not foremen generally should be expected to do manual labor with their men. This depends largely upon the amount of oversight necessary; upon the size of the crew, to some extent; upon the skill of the laborers; and upon the character of the work. In a large crew the presence of an overseer is always necessary. Human nature is so constituted that men gathered together in large bodies, for any purpose, lose more or less their sense of individual responsibility. Under these circumstances it is expedient that employees should have continually before them visible evidence that this weakness in humanity is known to the employer. The business of the foreman, then, while not actually engaged in giving directions, should be to stand around where he can see and be seen. But in small crews this is not so, necessarily, and a foreman should, in order to be profitable to his company, make it a rule to keep himself employed at something most of the time when not directing others. He need not necessarily be expected to fill the place of a laborer, at all times, but to at least do something which helps along the work in some way. There is always a certain amount of tinkering or work at odd ends to be done in order that all the men be kept at work with reasonable steadiness. In a small crew such things should usually be looked after by the foreman. One might inquire as to what number of men would in this connection, be considered a large crew, and what number a small one. This is one of those questions where it is difficult to draw a line, and one can hope only to offer suggestions; for very certainly no strict rule can be laid down. In a general way, a crew of less than six, besides the foreman, might be considered small, and one of more than eight, a large one. Between these two limits, it might be left for the foreman to debate in his own mind as to whether he should exert himself little or much. The rules of some roads require that foremen having fewer than five or six men must engage in work personally. It often happens that in work where men engage in pairs, such as tamping, spiking, tie renewals, and much other section work, the foreman can pair himself with the odd man, in case there be such, to good advantage. In many cases, therefore, roadmasters make it an aim, when reducing the forces, or when assigning the number of men allowed to each section, where the crews are small, to make the number exclusive of the foreman an odd number, like three or five, so as to give the foreman this opportunity of employing himself.

As is elsewhere stated in several connections, one of the most important duties of a section foreman is inspection, and this includes bridges and trestles as well as roadbed, or track on terra firma. He should carefully observe the surface and alignment of track on bridge floors, and the condition of the track fastenings in such places; the condition of bank sills and other end construction, the action of water around foundations; and, in fact, every condition which affects the safety of trains or the smoothness of riding thereof. To this end he should be required to ride over the track on the engine of a passenger train once in about every three months, going over several sections, so as to be able to compare his own section with the others. This gives a good opportunity to observe the condition of the curves with respect to elevation, and sometimes there are "soft places" under the track in such short stretches that the track springs back to surface as soon as it is relieved of pressure from the traffic. These are known as "blind sags," and the yielding character of the material is not apparent except while a train is passing. The engine will find all such places, if they exist, and when the foreman is aboard he should take note of the vicinity of each and afterward make it a point to be there while trains are passing, so as to discover the exact location. One remedy for a case of this kind is to raise the track up out of surface sufficiently to allow for the excess amount of yielding at the place. But if the cause is not plainly in view it is well to dig down and find it. In some instances a "hard place," like a log lying in a fill, just under sub-grade and diagonally to the center line, or a rock under one side of the track, has been found to be the cause of disturbance, without any sign of uneven surface in the rails when trains were not passing the spot.

Foremen should be encouraged in taking a lively interest in their work and in making an economical showing in the expense of keeping up their sections. They need, however, in some cases, to be taught the ill economy of temporarily keeping down expense by ordering insufficient amounts of material for repairs; allowing tools to go too long without repairing; failure to provide proper watchmen, on needed occasions; and possibly in some other short-sighted plans. Foremen should cultivate watchfulness, and the habit of observing things closely. In order to keep up with the times they should be regular readers of periodical railroad literature. There is no responsible position on railroads wherein the occupant is not better fitted for his duties by study and thinking. And then the better educated a man is, so much the better ought to be his control over the men working under his charge.

In the way of educational advancement a few roadmasters have adopted the commendable practice of calling their foremen together at regular intervals, once each year, or oftener, usually in the winter time, when work is not pressing, for a general discussion on track questions. The meetings are conducted in a manner somewhat similar to the procedure of the annual meetings of some of the railway associations. For example, the roadmaster acts as the presiding officer, and some weeks before the meeting he selects certain questions for discussion and sends a request to each foreman to be prepared to attend the meeting and discuss these questions.

At the meeting the foremen are permitted to conduct the proceedings pretty much in their own way, being free to give their experience and to criticise the methods of work and other matters brought out in course of the discussion. The results accomplished where such meetings are held regularly are said to be decidedly beneficial. In the exchange of ideas the foremen learn of new methods in practice and the meetings seem to stimulate a friendly rivalry which raises the importance of the work in the estimation of the foremen. It also conduces toward a uniformity in methods of work on the different sections represented. A supervisor on one of the large railway systems of the country, who introduced the practice of calling yearly meetings of his section foremen, has stated that such meetings were greatly enjoyed by himself and were found to be extremely interesting. He relates that the discussions were entered into with spirit and that progressive tendencies were readily traceable. He claims to have been much benefited on his own part, for in listening to the proceedings he was enabled to pick up many advanced ideas on the work of track maintenance. Mr. I. O. Walker, while roadmaster with the Paducah, Tennessee & Alabama R. R. (now part of the Nashville, Chattanooga & St. Louis Ry.), followed the practice of calling his foremen together four times each year. Other roads have various arrangements for the same purpose.

On the Chicago & Council Bluffs division (in Illinois) of the Chicago, Milwaukee & St. Paul Ry. there is a section foremen's debating society, organized in 1893 by Mr. Edward Laas, while roadmaster of that division. All the foremen of the division, to the number of 34, are members of the society, which has a constitution and by-laws, with officers elected yearly. The object is to meet and discuss questions pertaining to track and track work. All of the affairs of the society are conducted in a business-like manner. The meetings are held on Sunday, every two months, at Elgin, Ill., in a rented hall, in the business part of the city. Each meeting consists of two sessions, held during the forenoon and the afternoon. The meetings are conducted in parliamentary form. The proceedings usually consist in the reading of papers on methods and devices pertaining to track work, and in the reception and discussion of committee reports. Preparatory to these meetings the roadmaster usually suggests a subject or subjects to be taken up for discussion. The roadmaster is usually present, and occasionally takes part in the meetings, but the foremen are supposed to feel free to express their opinions and judgment on all questions brought before the meeting.

One of the results of these meetings is that the foremen are stimulated to think and study their work, and from such experience they are enabled to discuss track questions in an intelligent manner. Another important result has been that diversified methods of doing certain kinds of work have given way to standards adopted after careful and thorough investigations. On the other hand, by taking account of the conditions existing on different parts of the division, explanations are found for variations of practice in certain cases, where, without looking into the matter thoroughly, the various methods might not seem to accord with the best practice for the case. The fact that section foremen are at all times upon the ground and thus able to observe conditions and results in minute detail should make them authorities on a great many track questions. The periodical meetings of the society afford them the opportunity of analyzing the results and forming conclusions on methods of work and the efficiency of devices, which, without doubt, are valuable suggestions to the roadmaster and the purchasing agent.

The division superintendents of the Philadelphia & Reading Ry.

have in practice what are called "schools of instruction on the book of rules." In 1900 a committee composed of superintendents, division engineers and supervisors prepared a set of rules for the maintenance-of-way department. In connection with these rules there are illustrations, showing standards, and instructions concerning the use of material in work covered by the illustrations. After the rules had been published in book form the company inaugurated meetings on each division, at which section foremen and one or two of the more intelligent men from each section are required to be in attendance. Instruction is given by the supervisors and other competent instructors. At these meetings it is the endeavor to ascertain how each individual understands certain rules taken up for consideration, and his practice in connection with the same, the idea being, of course, to have all come to a uniform understanding of the rules and to hold discussion on all matters about which there can be any question. In this way the officers give the foremen such instructions as their talk would indicate to be necessary, and explain to them effectively any points that may come up in the meeting. These meetings are held at occasional intervals, and the discussions cover not only the rules laid down in the book but methods of doing work in general, the aim being to illustrate or exemplify the principles underlying the practice followed. The meetings have resulted in more uniform practice and a more strict adherence to standards.

Having been a section foreman, myself, I cannot resist the temptation to criticise certain defects and odious practices that are more or less widely tolerated or winked at by higher authority. It is my observation that some foremen are better qualified for the management of a large crew than a small one, for with the small crew they quite overdo the matter of overseeing. A small crew engaged at ordinary section work, especially if it be made up of experienced hands, ought not to call for the continual exercise of the foreman's vocal powers. Nevertheless there are many foremen, often well disposed men, too, who seem to take it for granted that every workman needs a certain amount of instruction each day, notwithstanding that the man may be quite familiar with what he is doing. And so instead of leaving competent men alone, and trying to make themselves of some use by their own efforts, as they should, they stand around fretting and actually hindering the work. Manual labor is not nearly so tiresome to endure as is the habitual fault-finding, irritating lingo of some peevish foreman; for when a man's mind gets tired he feels tired all over. Men working under such oversight will, in time, grow hesitant, lose interest in the work, and strive to do nothing more than to in some way meet the fancy of the "boss," or else to relieve their minds occasionally by provoking him all they dare. It is only telling the plain truth to say that hard taskmasters are not exceptional among track foremen. There are men in charge of English-speaking track crews in this country who fall a long way short of being gentlemen. Some foremen in giving directions to their men make habitual use of profane and violent language, repeating their tirades occasionally for the sake of emphasis. Judging from the language used, some track foremen seem to act on the proposition that the men are mules and themselves the drivers. Reference is not here intended to words occasionally spoken in anger, but to the every-day abuse which some foremen heap upon laboring men, who, under certain circumstances, perhaps, must endure it. Of course, such treatment of men can be regarded only as an indication of shameful ignorance combined with a little authority. Out of lack of confidence in themselves such foremen usually stand in continual dread of losing their positions, and they feel like keeping every one around them in the same stress of mind.

Although such demeanor cannot be charged as typical of track foremen as a class, it is nevertheless too largely followed in practice to be overlooked in any general treatment of track labor. It is hardly necessary to add that roadmasters ought not to allow such things to go on. No men working under such foremanship can take a lively interest in the work, and the result is damaging to the company from a dollars-and-cents point of view, even if there be no concern for the inhumanity.

189. Section Labor.—It is a commonly accepted notion that track work is essentially and necessarily the most ordinary type of labor—and such, indeed, some of it is. It is a great mistake, however, to regard all, or even the larger part, of track work, especially section work, as mere "puddling in dirt." The prevalence of the notion referred to may no doubt be explained on the fact that the occupation of the trackman is too frequently thought of in connection with the class of men who may chance to be following it in some certain locality, or class of localities, as in and around the large cities, for example. Taking the whole country into consideration, it is to be admitted that track labor is not up to the standard it maintained years ago. By this it is intended to say that throughout the country there are to-day fewer expert trackmen in proportion to railway mileage than there were, say, twenty years ago. One reason for this state of affairs is that of late years the country has been overcrowded with an ignorant, unskilled foreign element eager to work for a lower rate of wages than English-speaking laborers and their families could well subsist upon. As the result the low rate of wages paid has bid for nothing better than common labor, and but few who could get any other employment would seek labor at track maintenance or remain at it; and hence almost any man possessing an abundance of "main strength and awkwardness" has too frequently been acceptable.

Such is certainly a wrong state of affairs, for, notwithstanding that it seems to be the policy of railway companies to pay track labor no more than the lowest rate that is paid for labor anywhere, there is nevertheless in the occupation of the trackman as much scope for the exercise of skill and intelligent manipulation as will be found in that of the ordinary mechanic. An expert trackman is a skilled laborer, a tradesman—fully as much so as is a carpenter, a smith or a mason. Men cannot become expert at all kinds of track labor in a few months. A good, bright man would do well if he gained the necessary experience in two years. In order to acquire a good knowledge of things in that length of time he would have to have more than an ordinary opportunity, and at all times be prompt and willing to learn. As a rule young men do best at track labor, but unfortunately for the railway companies they do not offer enough inducement to always hold those who are most capable. In manufacturing districts, where better wages are usually paid for other labor, but few take pride in the work, and most of those who remain at it do so from force of circumstances, not being able to do, or not caring to do, more than to in some manner hold a job. In short, it seems that railway companies have failed to raise track labor, generally, up to the average efficiency which is certainly possible for it, if indeed such labor has not, as above declared, actually deteriorated.

The same aptitude for the work and the same qualities of character as were recommended in the case of the section foreman are of course desirable in the section laborer, although it could not be expected that their application would obtain so largely in practice, for in many instances it is a question of getting men of any kind or none. Nevertheless, as far as may be practicable, men should be sought who have a fair amount of intelligence, who are reliable, willing to learn and to do, and, of course, men who are physically able. Foremen should attempt to teach men all they can when the men first begin. Men are always more willing to learn at that time, and, besides, it should early be ascertained whether or not the man is going to make a success. It is a mistake to permit a man to work long without ascertaining what he can or will do. Special stress should be laid upon the proper use of tools; the way to handle the various tools; and the posture of the body which enables a free and easy use of any particular tool. Foremen should endeavor to explain the reason why such and such things are thus and so, and the object to be aimed at in any given kind of work, thus appealing to the man's intelligence.

But willing men cannot always make good trackmen. A man must have some aptitude for the work. If I was to name any one qualification which, above all others, is essential to skillful workmanship in this line I would call it *genius for matters of adjustment*; that is, the ability to see just what relation the different parts of any structure hold to one another, so that one may know just where and how to go to work on one part in order to put the whole into proper order or condition. I can refer to some examples which may set forth, more clearly, perhaps, just what I mean. Take, as an instance, the matter of lip at a stub switch. Now some men would see right away whether the lip was caused by a wrong setting of the stand, or by lost motion; and whether that lost motion was between head rod and rail, or between head rod and connecting rod, or between connecting rod and crank pin, or, whether it might not be due to loose or worn parts in the stand itself; or whether the gage of the moving rails corresponded to that of the lead rails; or whether the cause might not be due to a combination of two or more of such defects. But some men would never in all their lives be able to locate the trouble, and would therefore not know where to put in a key or what to change in order to right the difficulty. As other illustrations to the same point, take the lining of curved track; the proper point at which to place the lifting power in raising a low rail; how to pull spikes with a claw bar; how to most easily and rapidly put on a splice; how to secure the proper hold in lifting with a pinch bar, etc.

Good men cannot be retained on the section unless they can have steady employment. This means that, although it is usually necessary or advisable to reduce the section forces for the winter below the allowance for the summer, when most kinds of track work can be done to best advantage, it does not pay to lay off the entire crew, even if but temporarily, or to put all of the men retained on part time. There should always be retained a nucleus of from two to four men working steadily the year round. It is certainly to be doubted whether in the end anything is gained by laying off the entire section force during the winter season. Good men will not remain at employment where they are much needed during the hot weather only to be laid off or put on half time during the winter. The result of the prevalent system of working track employees is that the oldest (in service) and most capable men are constantly drifting into other kinds of employment, so that every spring the foremen must break in new men, whose work in general will not compare either in quality or quantity with the work of experienced track laborers. One of the drawbacks in securing and holding skilled labor on track is the uncertainty of steady employment. In an address before the Eastern Maintenance of Way Association, in 1900 (on "Skill in Track Maintenance"), I made the following comment on this phase of the situation:

"It is largely the practice, as winter comes on, each season, to either discharge trackmen or lay them off, or put them on short time, to reduce expenses. This practice causes the men to thoughtfully 'reflect on their summer's earnings', and the most industrious among them will look elsewhere for steady employment. The higher officials give their orders to have the men laid off and when spring comes the roadmasters and section foremen must procure and hold their labor the best way they can. In many cases a much better arrangement would be possible, even where retrenchment becomes necessary. For instance, roadmasters might be permitted to distribute the labor among the seasons in their own way, with a view to furnish steady employment to a goodly number of the oldest and most skillful section laborers. In very many cases this could be done, without sacrificing anything in economy, by postponing certain kinds of work until the winter season. The subject is worth a good deal of study, and in any case an improvement of the situation will call for some readjustment of the usual plans of doing work."

Water Boys.—In hot weather men should have plenty of good water to drink, if it can be had. Ice water is poor stuff for men who are not used to it, having a nauseating effect on those who are working and sweating; besides it does not quench thirst as well as does cool spring or well water. To protect laboring men against ill effects from drinking too freely of water while perspiring it is quite generally the practice to mix oatmeal or rolled oats with the water. When this is done the water vessel should be emptied and thoroughly cleansed each evening, as the oatmeal will sour over night. The drinking cup should also be scalded or scoured out, for obvious reasons. Where the supply of water along the section is not plentiful it is usually necessary to take a half or a full day's supply on the hand car. By carrying quite a large quantity in a keg or large jug wrapped in a wet blanket or covering it may be kept cool several hours. But where good water is in sight men always want it, and ought to have it. Where there are as many as six men in the crew it requires a good part of one man's time to supply the rest with water, if it must be carried some distance, and in such case it pays to employ a water boy with each crew, during the summer time or during hot weather. Such boys are usually paid about two thirds of a man's wages. When not occupied busily enough at carrying water he can be useful at running errands, looking after tools, and many kinds of light work, to keep him out of mischief.

190. Watchmen.—Track watchmen comprise track-walkers, crossing flagmen and gatemen, and special watchmen detailed to watch portions of the track liable to be endangered by slides, falling rocks, washouts, forest fires, etc. These men usually report to the section foremen. Track-walkers are regular watchmen employed to patrol the track, and on some of the busiest roads such watchmen are constantly in service both day and night. The usual practice is to walk over the track, following the freight trains in time to clear the track as far as possible ahead of the passenger trains. Thus a passenger riding from New York to Buffalo, say, on a through train, may quite likely be preceded all the way by watchmen on foot, each getting over his beat a few moments before the train arrives.

An ordinary day's work for a track-walker is to walk from 16 to 20 miles, making two round trips over a 4 or 5-mile section or beat. To do the walking alone usually requires altogether about six or seven hours, depending somewhat upon the way the track is filled in. He is required, however, to be out on the track, or near by it, a full day of ten hours, but not necessarily busy the whole time. The day track-walker is supposed to carry at least one tool of some kind. Part of the time it may be a light steel wrench, for tightening loose bolts; or a light hammer, referred to in the chapter on tools, for replacing broken spikes or driving down spikes which have worked up, or, with the pick end of the same, to clean out dirt or ice packed into the flangeways at highway crossings and behind guard rails. Sometimes he may carry a shovel, to drain puddles of water in the ditches. During snow storms he should carry a broom to sweep snow from point switches and spring-rail frogs. The day track-walker fills and cleans the switch lamps along his beat, except in yards where they may be too numerous. In winter time he lights the lamps and puts them up before dark, and takes them down after daylight in the morning. In the summer time, however, it is the duty of the night track-walker to put up and take down the lamps. Ashes dumped at water tanks on main line are usually cleared away promptly by both the day and the night track-walkers.

The track-walker should keep his eyes more or less on the rails ahead of him, and watch for spread spikes on curves. Spikes are most liable to spread in wet weather, when the ties are softened, and in winter when the ground is frozen and the ties are held rigidly in their beds. It is at such times that the curves are most liable to give trouble. In winter time he should watch the shims closely, replacing any which have worked out of place. He should take special notice of each frog, guard rail, switch, switch stand and connection therewith, and try the switch lock, to see if it is fast. In hot weather it is important to watch closely the moving rails of stub switches and report them when they run tight. The replacing of broken frog bolts and light repairs of this character may be attended to by the track-walkers. When telegraph wires are found down the track-walker should try to get at least one wire connected through; if not, he should call upon the nearest assistance he can get, after which he should report the break to a telegraph office or to his foreman, giving an account of the condition of the wires, poles, etc. He must see that cars left on side-tracks are fully clear of the main track; that derailing switches in side-tracks are properly set and locked; that doors of loaded box cars are locked or sealed, if not in charge of an attendant; that farm gates or other private openings upon the right of way are kept closed, and stock kept off the right of way; and put out fires which may get started on or near the right of way. Wooden bridges and trestles should be closely inspected for fire. When going off duty in the morning the night watchman should notify the foreman of delayed trains which have not passed.

The principal duty of a track-walker is, of course, to inspect the track. He is given only such other small duties as cannot well be attended to by the section crew, and is not supposed to do general track work, such as cutting grass, raising joints, etc. Indeed the man who walks 20 miles has plenty to do at that alone. Where there are numerous minor duties, 20 miles is too much, and the beat should be shortened. In any case the track-walker should not be burdened with duties too numerous to distract his attention from the real object of his position—that of carefully inspecting the track. If his time is too largely occupied with various other matters he is compelled to hurry over the track in order to make the end of his beat on time, and cannot therefore be expected to observe everything carefully. The night watchman is not supposed to carry track tools except, as above pointed out, a broom, during snow storms. A tubular kerosene lantern gives better light on still nights than a railroad lantern, but not on windy nights; neither is it so safe against blowing out. Some place a guard, consisting of a band of leather, around the lantern covering the open space at the top of the globe. This will keep it from being blown out in the wind, still in a heavy wind it will flicker badly and show poor light. It is therefore better to carry a railroad lantern on windy nights. The best way to light a lantern or switch lamp in windy weather, without means to shield it from the wind, is through the top, if the top can be taken off or swung back. For this purpose a piece of soft copper wire of small size, 6 or 8 ins. long, is a very convenient device for holding the match, if the opening is not large enough to admit the hand. It may be twined around the lantern frame or doubled up and carried in the pocket, and to hold the match the wire is wrapped around it a few turns.

Both day and night track-walkers should carry a watch, train schedule, red flag and torpedoes. A pocket rule or tape line should also be carried to measure the length of rail in case one is found broken. In lieu of such the rail may be measured as so many lengths of a stick of any convenient length. If the track-walker patrols past a telegraph office he should keep himself informed on the running of the trains, so that in case of any irregularity in the same he may arrange his trips according to the time they will arrive on or pass over his beat. After a watchman on single track has gone over his beat it is, under ordinary circumstances, useless for him to start back until a train has passed over it after him, and he should therefore wait. It is necessary, then, to have a cabin or shanty at each end of the beat, furnished with a stove, for a man cannot be expected to stand out of doors and wait during all kinds of weather. The same protection should be (and usually is) afforded watchmen at slides, or wherever the man is compelled to remain in one place for a considerable length of time.

On double track, track-walkers travel as much as possible facing the trains. They should make it an unvarying rule never to walk or stand on one track while a train is passing on the other track or is moving near by. Unless they are as prompt as clockwork about this they are liable to forget, some time, and meet with an accident. A track-walker should always observe closely every train which passes, the signals carried on the engine, and whether or not it is on time and, if not, how much late. Whenever he discovers a train parted, a car or truck derailed, or a dragging brake beam, he should by some means try to draw the attention of those in the caboose and signal them to stop. He can sometimes make himself very useful in this way.

Being under the section foreman's orders the track-walker is considered part of the section crew. His position is considered a promotion above that of section laborer and, as he usually works Sundays, he makes better pay. On account of the greater responsibility attached to his work he ought to be paid 10 per cent., or some such amount, more per day than the common track laborer. A track-walker should be a man who can be trusted. He ought to be a good trackman, temperate, and thoroughly reliable in every way. Without a knowledge of track and track work he may not, under some circumstances be able to properly judge of the safety of the track. He should be thoroughly acquainted with train signals—hand, flag, lantern, torpedo, and whistle signals. It is usual to keep the same man or the same two men steadily at watching, but sometimes a foreman will allow the section hands oldest in service to take it by periods in turn. It is a good plan to have the day and night track-walkers change about every month. Track-walkers find it easier on the feet to wear shoes having very thick soles.

Before sending out a watchman or track-walker the foreman should satisfy himself that the man will be competent to act properly in case anything is found wrong with the track. There are cases on record where watchmen, upon finding danger, have become so excited as to run several miles to get the foreman, taking no thought about holding the trains. When finding a dangerous place in the track, which he cannot repair, a watchman should stand by and see that no trains run onto it unawares. It is the duty of the trainmen to stop and call out the foreman if they are going that way. Of course it might happen that on double track the watchman could reach the foreman by going against the trains which use the track on which the danger lies. There have been instances where a watchman on single track, when trains were late, has found danger at such a time as not to know from which direction or how soon the first train would come. In such a contingency it might not always be possible to avoid trouble, especially if the danger be found on a curve, in a cut, and a heavy wind be blowing at the time. It would be unwise to attempt to get torpedoes out very far in either direction, and one might make a mistake in trying to get them out at all. Under such a consideration about the only thing to do would be to stand at the danger point until some indication of an approaching train is perceived, and then to get out in that direction as fast and as far as possible. One could quite likely get far enough to stop a passenger train in time. In a contingency of this kind at night a fusee would come handy. On single track it is never sure protection to put signals out in only one direction. Of course the first thing to do is to put out the stop torpedo signal the proper distance toward the first train due. A good rule to follow is to then run back to the danger point and, leaving a red flag (if by day) or red lantern (if at night) in the track get a stop torpedo signal out in the other direction a safe distance. Then run back to the danger point and go a little distance out toward the first train due, but not out of sight of the danger point after a train is due. As soon as a train is known to be coming near, get out toward it as far as possible.

With a good system of track inspection the chances are mostly in favor of the discovery of slides, washouts, burnt bridges, broken rails and other dangers in time to stop the trains. Nevertheless railway companies have been gradually falling away from the practice of employing regular track-walkers. One reason for this is that the length of road subject to trouble from slides, water or fire is comparatively short, and danger is most threatening when the weather conditions are unusual, at which times special watchmen are detailed to look after the track. Another reason is that broken rails are not so common as was the case 25 years ago. When iron rails were in use it was not an uncommon occurrence for a section foreman to find as many as three or four broken rails in the same day during very cold weather, and in those days it was the practice on some roads to give an extra day's pay for each broken rail found, to the trackman who first discovered it. Since stronger and better rails have come into use the tendency has been to dispense with regular track-walkers, except where conditions are unusual or during the coldest weather.

Another consideration is the cost. The expense of employing regular watchmen, or men to patrol the track constantly, is very considerable, amounting to about $90 per mile per year for one watchman during the 24 hours—that is, for either a day watchman or a night watchman—figured on the basis of a five-mile beat and wages at $1.25 per day. On most roads where the traffic is light it is simply out of the question to incur this expense except at places where, or at times when, danger is threatening. It must, of course, be understood that the number of trains running is one of the factors which have to do with the condition of the track respecting safety, for there are many ways in which a dangerous condition in the track may develop under traffic from a defect which is small at the beginning. Against trouble which arises in this manner an occasional trip over the track on some roads would afford the same measure of protection as regular trips at more frequent intervals over the track on a road carrying a correspondingly larger number of trains. As the amount of traffic under consideration in this connection increases it may be a matter of some difficulty to decide as to just when the need of regular track-walkers justifies the expense. It is one of those cases where a certain course is always known to be the safer, yet where the probability of accident due to not taking the precaution seems to be exceedingly small. There is no such thing as absolute safety at any expenditure. On roads where the traffic is light, and the rails of good weight and quality it may not be necessary to get over the track every day during summer, when the weather is fair; and if the section crews are small it is certainly not convenient to do so. It would seem, however, that all track should be inspected at least two or three times per week, at all seasons of the year. If obstruction or danger is liable to arise from conditions exterior to the track, such as sliding earth or rocks, fire or flood, that is, of course, a different matter.

Where regular track-walkers are not employed it is commonly the case that the section foreman or one of his trusty men is required to walk over the section, or ride over it on the hand car, at least once each day. In order to economize time it is sometimes arranged to have this man return by train and work the remainder of the day with the crew. On some of the long sections in the West the watchman is sent over the track on a velocipede, especially where he has to follow the trains and watch wooden bridges. On the Boston & Albany R. R. the foreman or one of his competent men is required to walk over the section in both directions every day in summer, and in both directions twice every day in winter. There are no night track-walkers except in stormy or rainy weather, when, as a rule, at least two men patrol each section at all times day and night. On the New York Central & Hudson River R. R. regular day track-walkers are in service throughout the year, the length of beat varying from two to five miles, according to the number of tracks. On sections where the conditions are unusual, such as track having a large percentage of curvature, track in dangerous rock cuts, tunnels etc., special watchmen are employed both day and night, their beats being usually limited to one half mile or one mile. They are required to patrol the track at stated intervals, usually just ahead of the schedule time of fast passenger trains. In some instances registering clocks are placed at each end of the beats, particularly for checking up night watchmen. On the main lines of the Pennsylvania road both day and night track-walkers are employed. On the Nashville, Chattanooga & St. Louis Ry. day track-walkers are employed during all seasons. The sections are from 6 to 12 miles in length, and the usual duties of the track-walker are to get over half of the section each day, tightening all loose bolts, carefully inspecting the track and taking note of all places that need attention. And so on it will be found that some railway companies follow the old practice of employing men to patrol the track regularly both day and night at all seasons, while others have cut this service down to that performed by day track-walkers only; others employ regular watchmen only during the winter season; while on the large majority of roads only such watchmen are employed as may be necessary to cover once each day that part of the section which has not been seen by the foreman. On some roads, even where regular watchmen are employed, the foremen are required to get over their sections at least once or twice each week.

Careful inspection of the track should be the principal duty impressed upon the mind of the section foreman. Nevertheless, it is often the tendency, during certain portions of the year, to reduce the amount of time devoted to inspection to the lowest possible limit which appears to be consistent with safety. Thus it sometimes happens that when hard pressed with important work, such as tie renewing or reballasting the track, a section foreman is inclined, during good weather, to keep his force at work as steadily as possible, sometimes sending a man to patrol the track each day, but quite frequently not. And so it comes to pass that, unknown to the foreman, the bolts in some frog may be breaking, one by one, while at some other point on his section cattle or other stock may be making a pasture field of the company's right of way, with now and then an animal killed. As a general proposition it is desirable that the section foreman should personally inspect his whole section each day or send a trusty man to do it. Under ordinary circumstances the results of careful track inspection do not always show plainly, since, as a rule, it is only when inspection is neglected for a considerable time that the results of such negligence are seen. For instance, the spreading of rails on curves usually takes place slowly, and if attended to when the spikes first begin to spread the difficulty is remedied before matters reach the danger point. The foreman who neglects inspection for a considerable length of time will frequently find conditions which could hardly obtain under a more frequent inspection, when tendency to disarrangement of parts is nipped in the bud, so to speak.

During very stormy or windy weather or at times of sudden thaws, especially at night time, when the track is liable to be flooded or washed out, or during extremely cold weather, the force of track-walkers is customarily doubled. During excessively hot days it is also necessary to watch the track carefully, particularly on very sharp curves, as trouble not unfrequently arises from the expansion of the rails. At dangerous cuts or sliding banks, and at streams which threaten to undermine the track, watchmen should be stationed to remain at one point or in the same vicinity. On sections where the switches are widely scattered it requires a considerable portion of a day's work for one man to walk over the track and light the switch lamps in the evening. On some roads where the track-walker makes only one trip each day he goes in the afternoon, in time to clean and light any switch lamps that may be distant from the foreman's headquarters. Men who attend to this work are frequently permitted to use a velocipede or light hand car. On double track it is safer to run such cars in opposition to the direction of the trains, as then the rider does not sit with his back to the danger (except where it is the practice to move some of the trains against the current of the traffic).

The necessity for night track-walkers depends, of course, upon the number of night trains running, particularly the number of fast trains; and so far as concerns the same measure of protection to trains the need of night track-walkers is more urgent than for day track-walkers, because in daytime the section men pass over some portion of the track; and then there is the greater probability that obstructions or defects in the track can be seen by the engineer in time to prevent trouble. In warm weather cattle, hogs and other stock are liable to break into the right of way for feed or to escape insects in the bushes, and sometimes they are found lying down or asleep on road crossings—in which event they are almost sure to derail a train if struck. In some cases where only one track-walker can be afforded during the 24 hours it would conduce better to safety to dispense with day track-walkers and have the track patrolled at night, while in other cases the arrival of the fastest trains on certain sections might make it advisable to have the track-walker employ half his time during the day and the other half during the night, arranging his trips to best protect the fastest trains.

Crossing Watchmen and Switchmen.—Crossing flagmen and gatemen and switch tenders are required to learn the schedule of the trains, the code of signals and the instructions in the book of rules and regulations regarding their position. On some roads they are examined every three years for hearing, strength of vision and for perception of color. Gatemen and flagmen are provided with red and white flags and lanterns, torpedoes and a train schedule. They use the white signals to prevent persons and teams from crossing when trains are approaching. The red signals are intended for use only when it is necessary to stop trains. Flagmen and gatemen are required to know the exact time when each regular train is due at the point where they are stationed, take particular notice of signals carried by the trains and be on the alert for irregular trains. They must prevent cattle and other stock from loitering near the crossing and prevent people from walking or driving over the track when a train is approaching, taking the same precautions for the passage of hand cars and gasoline cars as for trains. At crossings where the view along the track is obstructed the man on duty should be warned of approaching trains by automatic signal.

Some judgment is necessary in the time allowed for closing the gates or clearing the crossing while trains are approaching. Gatemen must be careful not to lower the gates upon persons or teams passing under, particular attention in this being required at night and while crowds are passing. The proper station for a flagman while trains are approaching and passing is in the middle of the street, at the side of the track, where he can be effective in stopping people who may attempt to drive across. Gatemen are required to keep the gates closed until the entire train has passed the crossing, and in case of double track they must not open them until they are sure that no other train is approaching from the opposite direction. After the passage of vehicles the crossing should be carefully observed, to see that the rails are not obstructed. In case the crossing becomes obstructed by a fallen horse, a broken wagon, a street car or by any other object not quickly removable, danger signals must be promptly displayed at a safe distance. At crossings where the street travel is slack during parts of the day the flagman or gateman is required to keep the flangeways clear. Defective crossing plank should be reported to the section foreman without delay.

On some roads the switchmen or switch tenders report to the roadmaster, and on others to the superintendent, but in yards it is usual for them to report to the yardmaster. It is the duty of switchmen to operate the switches under their charge, for the trains, and be responsible for their safe working. This requires careful inspection of the parts and frequent observation of the switch while trains are passing. In winter time they must keep the switches under their charge clear of snow, and at all times promptly report defects which they cannot repair. They have signals to display by day and by night, and as soon as the switch has been used, each time, they must set it for main line and see that the switch signal gives the proper indication. Where both day and night switchmen or watchmen are employed at the same point one is not permitted to leave the post until relieved by the other man. None but a total abstainer from liquor should be employed as a switchman or a crossing watchman, and these men should not be permitted to entertain loafers and other unauthorized persons in the watch house or vicinity thereof.

Bridge Watchmen.—Watchmen stationed at wooden bridges are required to walk over the structure immediately before each train is due, and in time to stop the train should anything be found wrong. On such trips they must always have danger signals ready for use in case of necessity. They are usually required to observe carefully the condition of the rails and fastenings and to pass several hundred feet beyond the ends of the bridge, to examine the track for broken rails and other defects. They must see that the water barrels are kept filled and that the means for handling water in putting out fires are maintained in good condition and always ready for use. After the passage of a train or engine the watchman is supposed to walk over the bridge and make careful examination of the floor and timbers for fires started, or to quench live sparks. In some cases they are required to carry a pail of water. The rules of some roads also require them to observe the ash-pan dampers of engines and report them when they are left open.

191. Length of Section.—The proper length of section on any road is a matter of importance and requires some study. On single-track roads the length varies from 4 to 10 miles, and on double-track, three-track and four-track roads from 2½ to 5 miles, being 2½ miles on most of the four-track roads. The proper length depends upon many conditions. The volume of traffic, the weight of rail, the quality of the ties, the kind of ballast, the number of switches; the condition in which the track is expected to be maintained; the condition of the track with respect to local elements of danger, such as slides, falling rocks, troublesome streams, and the clearing of land adjoining the right of way—all these have to do with the proper length of section. From a labor standpoint 3 miles of double track is considered the equivalent of about 5 miles of single track, conditions being the same in either case, and 5 miles of double track to about 8 miles of single track.

An all-the-year average of one man per mile of single main track or 1½ men per mile of double track, that is working force, exclusive of foremen and watchmen, is a general allowance supposed to be sufficient to keep in good condition a well-used track in gravel or equivalent ballast. The actual force allowed, however, is often regulated to correspond rudely to the earnings of the road, and in perhaps the majority of cases the general excellence of the track is determined upon that basis. A number of busy roads get along with ¾ man per mile, and some manage to reduce the allowance even further. Under ordinary conditions it is not profitable to keep the force constant in number at all seasons of the year, but to reduce it somewhat during the winter and increase it during the summer, when tie renewals, weeds, grass and low joints all seem to need attention at the same time. Five men for eight months of the year and two or three men for the other four months, exclusive of the foreman, is an ordinary allowance for 5-mile sections on single track.

It is not always a simple matter to compare the section labor of one road with that of another, even where the natural conditions appear to be the same, because some roads spend large sums of money to put the roadbed, track and right of way up to a high standard, after which it should be expected that maintenance expense can be reduced to a low figure. To illustrate difference of expense in relation to conditions of maintenance, consider that A., B. & C. Ry. is laid with heavy rails, tie plates, ties of long life, ballast of good quality and of good depth; that the roadbed has everywhere been constructed to a standard section, with wide shoulders on embankments and wide ditches through cuts, with surface ditches above the cuts; that the right of way has been completely fenced, snow fences constructed, etc. Now suppose that X., Y. & Z. Ry. is carrying traffic of equal volume and of the same class, and is required to be maintained in the same condition respecting surface and alignment, but is laid with lighter rails, on ties of shorter life, without tie plates; the ballast is dirty or of inferior quality, and insufficient in quantity; the roadbed is narrow on embankments and the cuts have never been widened to permit sufficient ditch room, and each season the section crews must put in several weeks extending the right of way fences. It is easy to see that the work of maintenance on this road is an entirely different proposition from that of the A., B. & C. Ry.

The number of men required for a section also depends a good deal upon the assistance which the section crew is supposed to render station agents, telegraph linemen, bridge and building foremen, tie inspectors, car repair men, surveying parties, fence crews, landscape gardeners and other of the company's servants; on many roads the men in charge of these various kinds of work are supposed to look to the section crews for help. The labor is, of course, charged up to the proper account, but, for a usual thing, it all comes out of what is generally supposed to be the allowance for the track. Again, some roads get along with small section crews because the heavy work, such as relaying rails, constructing turnouts and side-tracks, reballasting, raising sags, extensive ditching, handling material, fence construction, and frequently tie renewals, is all done by extra gangs. Some treatment of this plan of work is contained in the next section (§ 192).

According to the reports of the Interstate Commerce Commission the average number of section foremen per 100 miles of line has remained almost constant at 17 since the year 1890; and in 1902 each 100 miles of line represented, on the average, about 136½ miles of track, including second, third and fourth tracks and side-tracks. The number of trackmen per 100 miles of line, exclusive of foremen, averaged 105 during the same period (1890 to 1902 inc.), the largest being 140, in 1902, and the smallest 85, in 1894, since which time there has been a gradual increase. These figures do not, however, give a close estimate of the average length of section and the men employed thereon, because the number of foremen and laborers employed on yard tracks is not stated.

On poor roads, where the expenditure on the track must be reduced to the smallest possible figure, the sections are lengthened out in order that the force allowed may be collected into larger and more effective crews, instead of being scattered along in crews of two or three men in a place. The number of foremen needed is thus reduced and more than a proportionate number of laborers can be added by the saving so made. Up to 8 miles the advisability of this plan is certainly good, where the conditions demand it; and where the track does not, for various reasons, need an extra amount of watching, the length may even be made 10 miles; and such it is on numerous roads. The length of section ought not to exceed 10 miles where the regular daily trains exceed four in number, for that distance is about all one man can make a round trip over in a day on foot. But it is difficult and perhaps useless to lay down rules in such cases; for a road which can hardly keep running must do the best it can, for the time being, anything more than ordinary safety and convenience being necessarily secondary matters, seeming good policy to the contrary notwithstanding. Expediency rather than precept must be followed. On prosperous roads handling a fair amount of traffic, 5 miles is perhaps the most satisfactory length for single-track sections, and 4 miles for double-track sections, not taking switches or side-tracks into account. It is quite generally considered that the care and labor of attending to 12 or 15 switches is equivalent to that of attending to a mile of single track. On this point the Eastern Maintenance of Way Association has recommended that 15 switches and frogs (15 turnouts) should call for an extra man in the section force. Stub switches give the most trouble in summer and point switches during snow storms. The distribution of the switches makes a considerable difference in the work of keeping them in good condition and attending to the switch lights, as a number of switches near together are more easily looked after than the same number scattered over the whole length of the section. Two miles of important side-track or three miles of side-track but little used are considered equivalent to one mile of single main track.

The location of the section house or the foreman's residence is a consideration of some importance. So far as the duty of inspection is concerned it is not as convenient, and in some cases not as economical, to have headquarters at an intermediate point of the section as it is at one end. This for the reason that in sending one man to inspect the section he must first double back on part of the track before he can get over all of it. Where headquarters is at one end of the section, the foreman, in going to work with his hand car and crew in the morning, can, if desirable, first run to the end of the section and then on the way back stop at the points where work is to be done. If the crew is small this plan is about as economical as any. If he has a large crew he would most likely stop where the work is to be done and send a trusty man to walk over the rest of the track. In either case it is not necessary to lose time walking over track that has been covered by the foreman and the crew. Where he starts out each morning from the middle of the section or from some intermediate point, the usual plan is to send one of the men in the opposite direction, and then if the crew stops short of the end of the section to work it is necessary to send another man to inspect the remainder of the distance on that end. This man doubles that part of the section, the hand car or crew in course of the day doubles the part between the tool house and the point where the work was done, and the first man sent out doubles the part of the section in one direction from the tool house; and then, in order to reach the crew, to work the remainder of the day, he must walk over the part inspected by the foreman. The whole section is therefore inspected twice and part of it three times during the day. The plan of locating the section house and tool house at one end of the section therefore requires less walking in order that the inspection may cover the section daily than is the case where headquarters is at some intermediate point. If regular track-walkers are employed, however, the difference in the two arrangements is inconsiderable.

On the other hand, the foreman located at the middle of his section is the easiest found in the majority of cases of emergency. On sections where slides are to be frequently expected it might be advisable to locate the section house within convenient distance of the seat of trouble, and if this is as liable to happen on one part of the section as another, then the middle of the section will be the most convenient in the long run. Where sections are very long it is not desirable to locate the section houses at the opposite ends of any two of the adjoining sections, as that arrangement would bring a long stretch of track between the headquarters of section forces; on 10-mile sections the distance between section houses would be 20 miles. Of course, in some sections of the country the local conditions may be such that an arrangement of this kind cannot well be avoided, but in general cases the rule can be observed. Another important consideration, and in the majority of cases, perhaps, the most important consideration, is to have the section headquarters near a telegraph station, and a night telegraph station if possible. In thickly settled country it is usually feasible to do this. This arrangement puts the roadmaster in quick control of his track forces, and in times of emergency, as when wrecks and washouts occur, he can, as a general thing, mobilize them promptly. From the standpoint of hiring and retaining labor for the section crews, the plan of locating the foremen in the towns and villages, or at least in settled districts, generally gives best satisfaction.

192. Floating Gangs. On roads where there are a good many turnouts to lay, take up or change, or where there is enough of any kind of special work on the division to keep a considerable number of men busy, and still not of a kind that can be profitably done by the work train crew, it is customary to have one or more floating crews going from place to place to do such work. Such an arrangement relieves the section crews of extra work, thus enabling them to attend more carefully to the regular affairs of the section than would be the case if this work was to fall to them. On many roads it is the policy to keep the section crews employed strictly at the routine work of the section, such work as reballasting, laying new steel, extensive ditching, removing slides, repairs at washouts, widening banks, grading for side-tracks, laying new turnouts and side-tracks, etc., being attended to by extra crews or floating gangs. In times of emergency, as, for instance, when wrecks or washouts occur, the floating gang is generally in demand and can be used to good advantage, because the men are together and can be brought quickly to the scene of the trouble as a reinforcement. There is also more or less night work or work of a special character about the yards which this crew can perform to better advantage than the regular crews. Moreover, it is the practice on some roads to send the floating gang to help out section foremen who are behind with their tie renewals, or who have an unusual amount of such or other work on hand. The use of floating gangs to do common section work under ordinary circumstances, however, is not recommended as good practice, for it tends to relieve the section foremen of some responsibility, while foremen of special gangs are not usually disposed to assume any more responsibility in such things than the rules compel them to.

Just where to draw the line in the division of work between floating gangs and the section crews is something of an unsettled question, but many difficulties in this respect can be reconciled on the fact that the necessity for floating gangs on different roads does not always arise under the same combination of circumstances. Local construction work for which the regular section crew is not a sufficient force to complete it in the time required, or which comes during the season when the regular crew cannot spare the time, would seem to be one case about which there could be no question. Heavy repair work, like relaying rails or reballasting, which cannot be done economically by small crews, would seem to be another case of the same kind, but not many are in favor of taking ordinary repairs, such as recur every year, out of the hands of the regular section foremen. It frequently happens, however, that there is a scarcity of laborers in localities, and the section crews cannot be filled up to their regular allowance. In that event they must have help in order to get the regular work done in season. The point on which objection is most frequently raised is in regard to the poor quality of the work sometimes done by special gangs. As to this, much depends, of course, upon the reliability of the foreman and the kind of men he has to do the work; and right here it is well to point out the distinction between special gangs as they are differently organized.

An "extra" gang, as commonly understood, is a party of men organized for temporary service, usually for some special work during the busy season, and is then disbanded. It is usually got together quickly by hiring any available laborers, with little or no regard to skill, for skilled trackmen are seldom available for temporary employment. In the West such gangs are frequently composed of the migratory or "hobo" class of laborers, the most of whom are not in the habit of working in one place longer than until the first pay day. In other cases the gang is composed of aliens of the Dago or Polack nationality, who possess little or no skill and work in a leisurely and indifferent sort of way. Floating gangs are supposed to be organized for permanent service, like the section crews, and should be composed of a better class of labor than extra gangs. Ordinarily this gang is reduced when winter comes on, but the skilled trackmen are kept at work and the organization is maintained. There is usually enough work around the yards and terminals, such as shoveling snow, handling material, odd jobs about the switches and crossings, or occasional trips over the road with snow plows and flangers, assisting the wrecking crew, etc., to furnish steady employment. On some roads the gang is employed during winter time in stone quarries, getting out rock for ballast or for building purposes, while frequently there is track work enough to occupy their time the year round. These men, from their diversified experience, are supposed to be skillful at all kinds of track work, and even more ready to grasp new situations and adapt themselves to special conditions than ordinary section men. As for track work of a special character the chances are that the floating gang will do it more expeditiously and more economically than the regular section crews. When it comes to the point of temporarily increasing the size of a section crew by hiring a number of new men, in order to do some special work, there could hardly be any doubt about the advisability of sending the floating gang. Wherever the work of the floating gang will show distinctly for itself there is no reason to suppose that responsibility would be shirked. It would seem, therefore, that to this extent there need be no hesitancy about employing floating gangs.

In view of the aforementioned advantages derivable from floating gangs properly organized and supervised, they should be composed of capable, active and willing men. Unless they are willing workers they may take offense once in awhile when a "hurry-up" job is on hand or when, as sometimes happens, it becomes necessary to strain a point in order to complete the work in time to get off on a train. The floating gang as an apprentice school for foremen is elsewhere discussed (§ 188).

Men in floating crews, including the foreman, are usually paid a slightly higher rate of wages than ordinary section men—at least enough higher to cover the increased cost of living while traveling around. Such crews usually make headquarters at the division points. When the distance between headquarters and the work is too great to be covered in reasonable time by train, morning and evening, the crew arranges to board temporarily as near to the work as accommodations for transients can be had, going home usually on Saturday evenings. On many of the western roads floating crews are furnished with boarding cars, which are set out on the side-track nearest to the work, and go to and fro on hand cars. Floating crews are supplied with a full set of section tools and a hand car. When going to and from work by train, the work at the point being only of short duration, the tools carried along are divided between the men, who assist in loading them into the baggage car at the starting point and in unloading them at the stopping point. Each man being accountable for certain tools, is expected to see that they are all put into and taken out of the baggage car. If the work of the crew is to continue in one place for some time the whole outfit of tools, with a box to keep them in, and the hand car, should be shipped by freight.

The Ohio River R. R., before it passed under the control of the Baltimore & Ohio R. R., adopted for one of its divisions a system of track maintenance in which all the heavy work of the sections was performed by floating crews with districts regularly assigned. Under the previous system the sections were 7 miles long and were worked by a foreman and 6 men. Under the new system the sections were made 8 miles in length and were put in charge of a foreman and 3 men. In addition to this the division of 120 miles was divided into 30-mile sections, and each was worked by a floating gang consisting of a foreman, 20 men and a cook. Each of these gangs was provided with a boarding train consisting of four box cars and a flat car. One of these cars was divided and used as a kitchen and a living room for the cook; another was divided and used as a dining room, and a sleeping apartment for the foreman; and the other two box cars were used as sleeping apartments for the men. The flat car was used for supplies and materials.

The duties assigned to the section forces were to look after the small repairs, including the raising and tamping of low joints, or the light surfacing, and to inspect the condition of the track, keep the right of way fences in repair, maintain the grounds around the depots in a state of neatness, and such other work as the supervisor found it advisable and most economical to have this force do. The position of track-walker was abolished and the whole section force was required to go over its section every day with the hand car, inspecting the track, tightening loose bolts, driving spikes, etc.; thus in general doing all light work and seeing that the track was in safe condition. The larger forces, covering the 30-mile sections, performed all the heavier work of repair and renewals, such as placing ballast, renewing ties and rails, widening banks, ditching and such other work as the supervisor thought could be done more economically by this force than by the smaller section crews. The object of this organization was to secure better inspection for the track and to economize in the general work of track repairs. As the foreman was required to pass over the track daily, and was held responsible for the prompt repairing of defects, he could not divide his responsibility with a track-walker. The heavier work over each section of 30 miles being done by the same force, in charge of the same foreman, it was thought that more uniformity in the work was secured; that the forces were more nearly the size required to make such repairs economically; and that in case of wreck, in most instances, the force required could be more quickly and easily assembled. As the section foremen were still held accountable for the safety of the track in its minor, but not least important, repairs their responsibility was not lessened in any great degree. During the winter the floating gangs were cut down to 10 or 12 men and these worked only such time as was profitable. The men who worked in these gangs were young and single, as a rule, and as the quarters were made comfortable and board was furnished practically at cost, the most of them preferred to stay at the camp during the slack season. The company thus had at all times a large force for service in case of emergency. The management reported that the working of the system proved to be very satisfactory.

Fence Crews.—A man is sometimes employed to take charge of fence construction and repairs. When new fence is to be built he is given a small crew, with tools and facilities for transporting material, as described under the subject of fence (§ 151). When there is no new fence to be built he looks after fence repairs, where such are needed to any considerable extent. This arrangement is commendable, for the reason that he can see to getting the material to place better than any one else, thus avoiding delay. If he has no crew he is generally allowed to draw a man or two from the foreman on whose section the work is to be done. In the busy season it greatly facilitates matters to relieve the foremen of this work. Slight repairs should be kept up at all times by the section crews, but fire or flood will sometimes give them more fence work than they can find time to do.

193. Discipline.—In order to carry on the work of track maintenance to best advantage there must be conformity to well established business principles. The crew should report at the tool house promptly at the time set for starting out in the morning, which, by universal custom, is 7 o'clock. Section men should not be expected to run the hand car to and from work on their own time, because there is seldom or never a permanently established place where the work is done, from day to day, and also because one use for the hand car is to carry tools. It is customary, therefore, to run the hand car on the company's time. Some railways allow 5 minutes per mile going to and coming from work with the hand car. The foreman and all who habitually ride should help pump the car, and each should be expected to do a fair share of the work, too. Any foreman who is too lazy to work his passage sets a poor example for his men.

The foreman should see that each man does his work thoroughly, as well as that he does the proper amount of it. Indeed, at some kinds of work it were as well not to do it at all if it be not well done. The quality of the work is first in importance, the quantity second. Ordinarily a man should be expected to do a fair day's work, no less, no more. Very truly, the meaning of a "fair day's work" is something rather indefinite, but the term is generally understood to mean an amount of work performed at such a rate that an average man can keep it up steadily all day long without feeling tired out when night comes. The judgment of men on this point is quite liable to vary according to their physical endurance; that is, a very strong, active man might naturally expect more than would a man of ordinary strength. Now a good deal of worry and complaint on the part of foremen often arises over the fact that some men are physically able to do far above the average, and a foreman lacking in good judgment will expect that every man in the crew shall keep up with his "favorite." Surely this is not fair and it is very unreasonable. It is highly important that a foreman should know what an average day's work is. If he has been an observing man he should, from his previous experience, have learned how much of the different kinds of work ordinary men can do, and, consequently, know what to expect. The best results are turned out by a crew where the men are, as nearly as may be, on a physical equality, provided they do not fall below the average; for men do not usually like to be outdone by others in the crew, and those less able are liable unconsciously to slight their work in order to keep pace with the best. This is liable to occur in tamping, and it leads to bad results.

Having been a track laborer myself, for many years, I will venture a few observations. Some men do better at one kind of work than at another; as, for instance, some are not "built" for grubbing weeds with a shovel, but do well at other kinds of work. And again, some men are naturally a little quicker in their movements than are others. One cannot, therefore, expect to always get men to work alike. As long as a man is doing fairly well he is doing well enough, notwithstanding that some other man may be doing a trifle more than he. A fair-minded foreman can tell when men are making honest effort, and when each succeeds fairly well the foreman should not try to point out inequalities. Under ordinary circumstances I do not favor the practice of purposely placing men so that their work must show in competition. Such practice in working men is regarded by some foremen as a smart trick by which the men may be made to feel as though they ought to outdo one another. In some cases of the kind which have come under my observation, however, the aspect of things seemed to indicate that the foreman himself was a little in doubt as to just what he should expect of his men. Under such circumstances the foreman is quite likely to select as a criterion the pace set by some man who is trying to curry his favor. While temporary results may be accomplished by resort to such tactics nothing worth while is gained in the end. The men soon "catch on" and come to feel that they are distrusted and taken advantage of. In order to gain speed or make a showing they will slight the quality of the work, and when they engage in work where each man's part does not show for itself they are quite likely to take advantage of the foreman by doing as little as possible without being detected. Thus it goes "nip and tuck" between the foreman and his crew. Unless employees are encouraged to perform their work in the proper spirit the results are likely to be defective in some respect. But the foreman who understands his business can get the proper amount of work out of his men without setting up a contest among them. A man who cannot keep up a fair rate of work without hurry and worry is not a good man to retain in the service, and neither is he who is continually jumping into the work purposely to show off to disadvantage the work of some other man who is doing enough. Men of the latter class will not always keep up such activity when working alone, for in over-exerting themselves they usually have some particular end in view.

Foremen should endeavor to carry on the work methodically. One respect in which this principle may be furthered is to get men into the habit of so distributing themselves about the work that they will keep out of one another's way, as much as possible. Some men are quite clever at prearranging things so that they get a chance to move about often, or perchance to so block matters that they will have to stand idle while others work. An instance: Suppose that a rail has been raised and the ties are to be tamped. If two sets of tampers begin at the ends of the rail and work toward each other they get into each other's way near the middle, so that one or the other set must tamp the last three or four ties while the other set stands to look on, thus wasting time. Now if one set had begun at one end of the rail and the other set at the middle of it, and both had worked in the same direction, the work would have been properly divided and there would have been no interference. Men should be taught the importance of making every stroke count. Some men fly around and make a good deal of fuss without accomplishing much. The foreman should impress upon them the importance of doing the work with as few movements as possible. It is easy sometimes to mistake exertion for achievement. In very hot weather men cannot be expected to do quite as much as when it is cooler.

It sometimes becomes necessary on railroad track to do work on Sunday. It is not a good plan, however, to make a practice of looking for work to do on this day. Men are always able to work more cheerfully and energetically where they have one day out of the week for rest. In cases of emergency trackmen should expect to respond to call for duty, whether it comes at night, on Sundays, or at other times, but when the work on hand is that of mere expediency, foremen or laborers having scruples against Sunday work should be excused from such service without prejudice to their regular employment. Men should not be obliged to work on legal holidays unless the work is very pressing.

On most roads section men are forbidden to trail the hand car behind the caboose of freight trains, as such practice frequently results in a broken hand car and injury to some of the men. Such damage or injury usually occurs by the sudden stopping or slackening in speed of the train, when the hand car will dart under the caboose platform, breaking the lever and squeezing the men at the head end of the car. If proper precaution is taken there is no danger, as the men may ride on the caboose and the car can be drawn by a stout rope and prevented from running into the caboose by a pole planted against the gallows frame. On mountain roads, where the speed of freight trains up grade is slow, the section men are much tempted to hook on behind, for it saves a good deal of time, but unless the practice is forbidden or regulated in some manner the men are liable to take risks and get into trouble. Foremen should see that hand cars and trucks are clear of the track in good season for the regular trains, and they should not permit the men to throw switches when trains are about due. On double track velocipedes should be run opposite the running direction of the trains. When visiting his foremen the roadmaster or supervisor should habitually compare watches, to see that correct time is carried on the work. Foremen should see that the men get clear of the track well in advance of approaching trains. Carelessness in this respect causes no little uneasiness with the enginemen. And when standing out of the way of trains men should neither be required nor permitted to rush into the track to work immediately the rear coach passes. Such movements look bad and ought to be noted by the roadmaster with some degree of suspicion, for men are seldom as eager to work as all that—if they were they might sometimes forget themselves and leap into danger, as in the case of a break-in-two.

Foremen should be very careful how they use their switch keys and very solicitous concerning the use of the same when entrusted to their men. It should be an unvarying rule not to unlock switches for letting hand and push cars through, unless they are loaded so heavily that they cannot be easily lifted over, near the switch. When using a switch for this purpose the man who unlocks it should remain by the stand to throw it back to place and lock it for main track after the car passes. Switches must sometimes be thrown while working at them, and on such occasions men are more liable to forget themselves than in any other way. There is a rule which, if followed, will save foremen much anxiety, many times; and that is to always run the hand car over the switch, on main line, after work has been done on it, before leaving. In stopping the hand car for a little while to do a piece of work at a switch, the car should always be stopped short of the switch, so that when leaving the place the crew cannot go off and forget to close the switch.

The Brown System.—In the operation of railways occasion frequently arises for disciplining men for mistakes, neglect of duty or other shortcomings not thought to be sufficiently serious to require the employee's discharge. A method commonly followed in such cases is to reprimand for slight offenses and to suspend the employee from duty, with loss of pay, for such other offenses as are not thought to be deserving of dismissal or discharge. The punishment of employees for offense of any kind is always an unpleasant duty, and the best course to take in general cases is a large and somewhat perplexing question. During late years this question has been much discussed among railway officials of all grades, and the tendency of the times seems to be toward the adoption of what is known as the Brown system of railway discipline or "discipline without suspension," first applied to railway management by Mr. Geo. R. Brown, while general superintendent of the Fall Brook R. R. In the operation of this system the employee at fault is disciplined by record, and, as already intimated, without suspension. As conducted by Mr. Brown, himself, a record book was kept in which was written down a brief statement of every irregularity for which a man was responsible, this record taking the place of the usual "lay off." When a man began to "make a record" he was called in and reminded that if the same became too long he would have to be considered a failure for the service, but would be given another chance. If the admonition had the desired effect, as shown by the man's future conduct, he was retained in the service, but if, on the contrary, he reasoned that the record was an easy way out of the trouble, made light of it and was frequently called on to explain irregularities, he was dismissed from the service.

This original system has been modified in many ways, but the same essential principle is retained. A very common arrangement is one in which a system of merit and demerit marks or a nominal suspension of a certain number of days is substituted for the usual punishment feature, so that the standing of the employee is at all times determined by the record of merit and demerit marks or nominal suspensions entered on his account. For each offense requiring disciplinary action the employee is charged with a certain number of demerit marks, after the manner employed by old-time school teachers; and for acts of special merit he is credited with merit marks, which may cancel a like number of demerit marks. Employees having a clear record for some given length of time, like six months or a year, are entitled to a certain number of merit marks, but a bad record is followed with dismissal.

Another feature of the system, which also was originally put in practice by Mr. Brown, is a bulletin board on which are posted at stated periods brief accounts of mishaps, irregular conduct and other occurrences, pointing out errors and consequences, with criticisms thereon, but omitting, however, the names of individuals or any hint at their identification. This bulletin is intended to make accidents and other matters a lesson to all the trainmen, and in cases attempts to show how the errors might have been avoided. In usual practice meritorious conduct worthy of special remark is also bulletined and commented upon.

The Brown system of discipline, or modified forms of it, is now in force on more than one third of the railway mileage of North America. Some of the advantages of the system, as applicable to the track department of a railway, are well set forth in a paper by Mr. H. W. Church, while roadmaster with the Lake Shore & Michigan Southern Ry., read before the annual convention of the Roadmasters' Association of America, in 1898, here quoted, in part, as follows:

"In the event of a suspension it is necessary to put a substitute in charge, who, as a rule, is less skillful, lacks knowledge of the locality and conditions, and where the suspension is for a considerable length of time the company would suffer because of this lack of skill and knowledge. The suspended employee would not only lose his time, with the consequent hardship entailed upon his family, but would form a secret dislike for his superior and the company he serves. With the Brown system, instead of the employee losing his time and his family being inconvenienced, if not immediately suffering by reason of his enforced idleness, a given number of demerit marks would be entered against his record. The company would be the gainer by his retention in the service, not having to educate a new man, with the possibility ever present of his making a still greater mistake. The retained employee would feel his error more keenly and would, I think, be less likely to err in the future, and so far as the others are concerned the lesson would be equally as good. . . . . Be content, therefore, with moderate measures and moderate results; advancement is made only by slow degrees, and not in one jump. Have your men feel that you are their friend rather than their natural enemy; that your interests are mutual, and that their acts reflect credit or discredit upon you. Above all, bear in mind the truth that 'The aim of discipline should be to produce a self-governing being; not to produce a being to be governed by others.'"

Mr. Brown, himself, has said: "It often occurs that the disgrace and injury occasioned by a strict enforcement of a sentence does more to ruin the guilty than anything else, and a wise provision has been made allowing courts to use their judgment as to carrying out punishments; this is known as 'suspending sentence.' If the sometime offender does better, and is not guilty of the same or other offenses, the judge conveniently forgets the indictment hanging over him, but should he go on committing one misdemeanor after another, his 'record' rises up to condemn him. I believe in the practice of 'suspending sentence' with railroad employees.

"With this system the good men are retained, developed, benefited and encouraged, and the culls are got rid of to the betterment of the service all around. . . . . Every wreck, every accident, every mistake, every loss has taught its lesson, and these are of no less value to the railroads and to railroad men than the successes. I practice making every mishap a lesson to every man on the road. It often happens that an accident, or a 'close shave' for one, is the best kind of a lesson to the man who could be blamed; and if he is retained in the service, he is a more valuable man than he would otherwise be or one who could be hired to take his place."

In dealing with employees the essential thing for the official in authority to know is whether the employee whose conduct has been called in question is competent for the duties with which he is charged, is trustworthy and who enters into the work of his employer with the proper spirit. There is hope of any employee who fulfills these requirements, notwithstanding a fault may be chargeable against him for some occasion or other, and in the minds of many or most progressive railroad men there is hardly any doubt but that with such men the Brown system of discipline will accomplish the most satisfactory results. On the other hand, the man who fails to measure up to these qualifications should be dismissed from the service as soon as his employer or foreman is satisfied that his character has been correctly estimated. It should be borne in mind that all systems or methods of dealing with men have their limitations; and the benefits of any scheme of retrievement like the Brown system should not be extended to any man unless he is earnest, competent, straightforward and really capable of improvement. Neither the Brown nor any other system can make a lazy man industrious, or an interested workman out of a man whose chief concern is "sundown and pay day"; neither can it make a careless man careful, or a drinking man temperate or change his character in any material respect. The man's character and habits constitute the basis to work upon, and if it is seen that these are incompatible with his responsibility his dismissal should not await the announcement of a formal record of errors.

Discipline should never be so irrationally stringent as to discount the manhood of the employees. Instances have been known where subordinate employees or officials would secretly criticise some certain rule, pet notion, device or method of a superior officer, which was working trouble or ill economy, but with evident solicitude about their views being known at headquarters. Men in authority should let it be known that criticism of existing rules, methods or other matters, from employees of any rank, if presented in reasonable form, will be appreciated. If intentions to this effect were generally made known in the printed books of rules and instructions for railways it is just possible that some companies might profit thereby.

In connection with the duties of section foremen (§ 188) mention is made of certain difficulties which sometimes arise purely from the personal relations between a foreman and his men. The rules and instructions of a number of roads suggest others of similar character. Not a few railway companies find it necessary to forbid such transactions as the borrowing or lending of money between an employee and his foreman; the contribution of money for the purchase of testimonials to superior officers or the giving or receiving of presents of any kind; or the asking or receiving of money or other consideration for employment given. There are also rules forbidding any officer or foreman to prescribe to subordinates where their personal purchases shall be made. Such rules are undoubtedly justifiable, and it is possible to extend their scope still farther. In my own experience I have witnessed many a "hot time" in gangs of trackmen stirred up over gambling during the noon hour or in the boarding cars at night. Foremen should be forbidden to engage in such practice or to permit it among their employees, about the work or in company buildings or cars. When the gambling fever strikes a crew it seems that card playing then becomes the chief occupation of some of the men for days and nights at a time, and sooner or later matters terminate in a row.

Some of the worst infractions of discipline result from a too frequent use of intoxicating liquors. Most railway companies have rules prohibiting the use of intoxicating drinks *while on duty*. It is well known, however, that this rule comes far short of accomplishing its object, for it does not literally meet the case of the man who "fills up" *just previous to coming on duty*, or who carouses around at hours when he ought to be asleep. An employer has a right to expect that his employees shall have clear heads at all times while on duty, and this cannot be expected of men who will go on their little sprees Saturday nights, or on pay-day night, or "of a Sunday," or of men who drink with any degree of regularity, no matter how little. And then, in the foreman's case, his working hours may occasionally come at any time during the twenty-four, and he should therefore keep himself always in fit condition to be called out at any time. It is, perhaps, not in keeping with democratic theory to attempt any restriction upon an employee's drinking while off duty, and it is certainly futile to so attempt. But there can be nothing "unconstitutional" in the practice of choosing foremen from among men who do not drink at all, and it is the wisest plan to follow. Then any man found to be in the habit of drinking, after having represented himself otherwise, has shown cause for dismissal; for clearly he has either misrepresented or else he has degenerated.

194. Reports and Correspondence.—It is perhaps unnecessary to say that accurate reports, embodying all work done and all changing of materials on each section, and by each working crew, should be made out on systematically arranged blank forms and sent to headquarters at regular intervals. The most common reports regularly made are: Monthly time sheet, distribution of work (monthly), weekly report of work, monthly report of materials, monthly tool report, daily and monthly work-train report. Besides these regular reports there are a number of special reports in common usage, such as report of new side-track laid, report of side-track taken up, report of stock killed or injured, report of casualties, fire report, report on rail failures, report on new buildings or other structures adjacent to the track.

The exact wording of blank forms, as well as the matter of detail reported, differs with different companies, owing to conditions and circumstances local or peculiar to each, and to the different ways in which different officials choose to look at statistics—which usually amount to matters of taste only. The reports should be simple and consistent and full instructions should be noted on each blank, so that foremen may fully understand how it is to be filled out. Trifling matters should not be made subjects for special report (as is sometimes the case)—the aim should be to report as many matters on the same blank as may be practicable. On some roads all work performed on main track is reported on a single form, and likewise all materials accounted for are reported on a single form. Wherever such practice is possible without too great inconvenience it is a commendable one to follow. The making of numerous reports "is a weariness to the flesh," and waste of energy thereon begets the habit of attending to such matters thoughtlessly. The adoption of a "set of standards," a code of rules and a multiplicity of report forms does not necessarily make for system in track work.

Time Reports.—As most railroad companies pay their employees monthly, the time book or time sheet is made out and forwarded at the end of the company month, which, with some companies, by the way, does not correspond with the end of the calendar month. It is, of course, important that all records should be made in ink, or with indelible pencil. The foreman should make out his time book daily, as this is the most businesslike method and one the least liable to incur mistakes. A blank for a time sheet or page of a time book is shown as Form 1, and for the purpose of explaining some points connected with the transferring of time to the distribution sheet, it is filled out. All time worked should be entered in the time book, and whenever a time card is issued, note should be made of the same in the column for "Remarks." Bad weather, which interferes with the work of the section, should always be noted in the time book. Some roads require section foremen to make note of the weather daily.

Owing to the roving habit of railroad men in some parts of the country there would be great difficulty in retaining employees in service if there was not some security provided for their board bills; for but few traveling men of that class have means to pay in advance. It is customary on railroads to deduct board bills from the pay of employees when such bills are presented at the pay car or sent in along with the man's time. Hospital bills or dues are also deducted on many roads. On some roads regular hospital dues of about a half dollar per month are collected from all employees without the formality of asking consent. In case of accident or sickness of any kind the employee is then entitled to care and medical treatment free of charge. Strange as it may seem, whiskey or drink bills have

Railway Company.

Northern Division, Section No. 5 at Hampton Station between Mile Post 36 and Mile Post 42

MONTHLY REPORT OF TIME for the Month of June 1896

No.	NAME	OCCUPATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total Hours	Total Days	Rate Per Day or Month	AMOUNT	No.	DEDUCTIONS To Whom Due	For What	Amount	BALANCE DUE	REMARKS
1	Grady	Foreman	10	10	10	10	10	10	S	10	10	10	10	10	10	S	10	10	10	10	10	10	S	10	10	5	X	10	10	S	10	10		245	24.5	$50 00	$50 00	1				$50 00	
2	O'Brien	Day Track Walker	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	X	10	10	10	10	10	10	10	10	10	10	10	10	10	10		290	29.0	1 20	34 80	2				34 80	
3	McCarty	Night Track Walker	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10		300	30.0	1 20	36 00	3				36 00	
4	Kelley	Laborer	10	10	10	10	10	10	S	10	10	10	10	10	10	S	10	10	10	10	10	10	S	10	10	5	X	10	10	S	10	10		245	24.5	1 20	29 40	4				29 40	
5	Sullivan	"	10	10	10	10	10	10	S	10	10	10	8	10	10	S	10	10	10	X	10	10	S	10	10	5	X	10	10	S	10	10		233	23.3	1 20	27 96	5				27 96	
6	Doyle	"	10	10	10	10	5	10	S	10	10	10	10	10	10	S	10	10	10	10	10	5	S	10	10									190	19.0	1 20	22 80	6				22 80	Time Card given 6/23/96
7	Murphy	"	10	10	10	10	10	10	S	10	10	10	10	10	10	S	10	10	10	10	10	10	S	10	10	X	X	10	10	S	10	10		240	24.0	1 20	28 80	7	John Smith	Board	$14 00	14 80	Board Bill Rendered
8	Olson	"	10	10	10	10	10	10	S	10	10	10	10	10	10	S	10	10	10	10	10	10	S	10	10	5	X	10	10	S	10	10		245	24.5	1 20	29 40	8				29 40	
9	Peterson	"								10	10	10	10	10	10	S	10	10	10	10	10	10	S	10	10	5	X	10	10	S	10	10		185	18.5	1 20	22 20	9				22 20	
10	Larsen	"																								5	X	10	10	S	10	10		45	4.5	1 20	5 40	10				5 40	
11																																						11					
12																																						12					
13																																						13					
14																																						14					
15																																						15					
		TOTALS	80	80	80	80	75	80	20	90	90	90	88	90	90	20	90	80	90	80	90	85	20	90	90	50	20	90	90	20	90	90		2218	221.8		$286 76				$14 00	$272 76	

Patrick Grady Foreman

Form 1.—Time Report.

been guaranteed and paid by some railroad companies in connection with board bills. No deduction should be made from any man's pay for board unless a written bill is presented. This bill should be forwarded by the foreman with the time sheet, and when the account is paid by the paymas-

Railway Company Northern DIVISION

MONTHLY REPORT ON DAILY DISTRIBUTION OF WORK. On Section No 5 For the Month of June 1896

CHARGE TO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	No. of Lin. Ft. Cu. Yds Pieces	TOTAL HOURS	RATE	COST	LOCATION	REMARKS
1 General Repairs							S					10		S		7		5			S							S		4			26	12¢	$20.60 3.12		Foreman $20.60
2 Watchmen	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20			600	"	72.00		
3 Line and Surface												60	70	S	66	53	70	43	70	65	S	70	70									8280	637	"	76.44	M.P. 37-40	
4 Ballasting Old Track																																					
5 Cutting Grass Rt of Way																										10	10	S	10	10		2400	40	"	4.80	M.P. 40-41	
6 Cutting Grass in Track					25			70	70	70	68															21	40	S	40	36		28440	440	"	52.80		Promiscuously over the Section
7 Cutting Brush																										20	20	S	20	20		4950	80	"	9.60	M.P. 40-41	
8 Putting in Ties	60	60	60	60	30	60																										594	330	"	39.60	M.P. 41-42	
9 Replacing Rails																																					
10 Ditching																										14						220	14	"	1.68	at 38¾	
11 Repairs Frogs and Switches																		12						Rain	Rain								12	"	1.44		McInnes Bros. Spur
12 Repairs Bridges and Culverts																																					
13 Repairs Tools																								30									30	"	3.60		Repairs to Hand Car and Grinding Scythes etc.
14 Repairs Side-Tracks																																					
15 Repairs Fence															4											2						96	6	"	.72	[illegible]	
16 Repairs Telegraph																										3						350	3	"	.36	at 39¼	
TOTALS	80	80	80	80	75	80	20	90	90	90	88	90	90	20	90	80	90	80	90	85	20	90	90	50	20	90	90	20	90	90			2218		$286.76		

Patrick Grady FOREMAN.

Form 2.—Report on Distribution of Work.

ter or other agent the bill should appear and be properly receipted. In some cases a page of the time book is headed and ruled for explanations of deductions, the column headings reading thus: Name—Board—To Whom Payable—Address—Amount—Hospital—Total—Remarks. In other cases the time sheet itself or each page of the time book is ruled and headed to insert the deductions from each man's pay, if there are any. This arrangement is shown on Form 1.

The time of monthly men not working a full month is usually computed by multiplying the rate per month by the number of days worked (including Sundays and holidays) and dividing this product by the total number of days in the month.

Men discharged before the end of the month are usually given a "time card" by the foreman. The customary routine is to send this time card to the headquarters, or to the paymaster, and a check or the cash is forwarded to the nearest company agent with orders to pay it. If the man discharged is not known to the agent, or at the headquarters, in case he wishes to present the time card there, he is required to put his signature to an identification card which the foreman sends to the roadmaster's or paymaster's office as soon as the time card has been issued. If payment is made through one of the station agents this identification card is enclosed with the check in the letter sent by the paymaster to the agent, who is thus able to identify the man by his signature. If the man cannot write, it is, of course necessary for the foreman or some other responsible party to identify him in person. Forms 3 and 4 (face and back) show the usual blanks for a time card, and Form 5 shows an identification card. On some roads blank time cards are not issued to the foremen until an application has been made for the exact number needed. This precaution is intended to prevent forgery. In giving a time card to a man who has not received pay for work done in the previous month it is usual to wire a request to the paymaster to forward the whole amount due the discharged employee to the agent nearest the section.

................R. R. Co.

..................................Division.

TIME CARD.

To be given only to men leaving the service of the company.

No.......

NOT TRANSFERABLE.

(Place).............(Date)..................190....

TO...

Roadmaster,

(Place).......... .. ..

Please order pay sent to.. for ....days' work as ....on Section No........... during the month of ....190......@...........per day $......

Deduct for board to .... $........

" " " " .... $........

Total Deduction, $........

Balance due, $........

Send in care of.....................at.....................

He was discharged on account of...........................

....................Foreman, Section No............

Approved............................

Roadmaster.

[Over.]

Form 3.—Time Card (Face).

Instructions to Foremen.

Whenever you discharge a man before the end of the month you must, in case he desires his pay at the time, fill out this time card and either give it to him or send it to this office. Have him sign his name to an identification card, which you will send immediately to this office, yourself. If the man is not discharged give the reason why he quit. Men who quit of their own accord will not be paid before the regular pay day, unless removing to a distance or because of some other extraordinary circumstance. When application is made for a time card you must, therefore, use judgment accordingly.

Deduction for board will not be made unless an itemized bill from the landlord is sent through the foreman.

....

Roadmaster.

Form 4.—Time Card (Back).

If special blank forms are not furnished for it, two or three pages of the time book should be headed for a description of new work, wherein should be noted all such work as grading and the laying of new track, or side-track, fully described as to location, nature of the work, etc. A convenient arrangement is to have the time book and report on distribution of work under one cover. The two are then together, which subserves the convenience of both the person who makes out the reports and the one who checks them over.

Distribution of Work.—The monthly report on "distribution of work" or "division of labor" shows the amount of labor chargeable to each kind of work performed, in hours, each day, and the amount of work accomplished. The total time worked, as shown by this report, must of course check with the time sheet for the same period. Form 2 shows the ordinary arrangement of this report. One arrangement where the time book and report on distribution of work are combined in the same report is to devote a separate page of the time book to each laborer, headed horizontally as a time sheet, with a list of the various kinds of track work in the left-hand vertical column. In entering the time worked the number of hours

(Face.)

.......................R. R. Co.

..................................Division.

IDENTIFICATION CARD.

This will identify..................................discharged from Section No......., on ...., 190....

Signature of.................. ....

Foreman.

[Over.]

(Back.)

Instructions to Foremen.

When discharging a man who desires his pay at the time, have him sign his name in the blank space at the left, on the face side of this card and send it to this office by first train.

....

Roadmaster.

Instructions to Agents.

To identify the payee have him sign in the blank space at the left, on this side of this card; then fold the card over and see that the two signatures are alike. Return this card with the receipt from the payee.

Signature of ....

Paymaster.

Form 5.—Identification Card (Face and Back).

devoted by the man to each kind of work during each day is marked opposite the kind of work appearing in the left-hand column, and at the bottom of the sheet the total figure for the day corresponds to the number of hours worked that day. The vertical column of totals at the right-hand side of the sheet shows the amount of time for each labor account at the end of the month, and as footed at the bottom it checks with the total time worked by the man during the month. As above stated some roads have separate reports for many kinds of work, such as laying rails, ballasting, building fence, etc., instead of, or in addition to, the inclusion of such items in the report on distribution of work. This plan, of course, multiplies reports, in some cases unnecessarily, and the extra reports should be dispensed with as much as possible. Below is a list of items or line headings commonly used in reports on distribution of work. All of these items would not likely be found in the report of any one road, but the list shows what items are used on some roads. It is usual to leave at the end of the list a number of blank lines for the entry of time worked on odd jobs of work for which no headings are printed.

1. General Repairs.
2. Watchmen.
3. Line and Surface.
4. Ballasting Old Track.
5. Cutt'g Grass Rt. of W'y.
6. Cutting Grass in Track.
7. Cutting Brush.
8. Putting in Ties.
9. Replacing Rails.
10. Ditching.
11. Laying Tile.
12. Repairing Frogs and Switches.
13. Repairs to Bridges.
14. Repairs to Culverts.
15. Repairs to Tools.
16. Repairs to Side-Tracks.
17. Repairs to Fence.
18. Repairs to Telegraph.
19. Repairs to Snow Fence.
20. Highway Crossings.
21. Cattle Guards.
22. Policing.
23. Building Fence
24 Building Snow Fence.
25 Work on Sign Boards.
26. Removing Snow and Ice.
27. Removing Slides.
28. High Water and Wash-outs.
29. Handling Materials.
30. Tightening Bolts.
31. Shimming.
32. Handling Freight.
33. Handling Fuel.
34. Loading Ballast.
35. Loading Ties.
36. Loading Rails and Scrap.
37. Grading for New Track.
38. Laying New Track.
39. Ballasting New Track.
40. Construction New Side-Track.
41. Filling in Bridges.
42. Widening Embankments.
43. Riprapping Banks.
44. Wrecking.
45. Taking up Track.
46. Cleaning Culverts.
47. Removing Stumps.
48. Cutting Down Trees.
49. Disposing of Killed or Injured Stock.
50. Work at Water Tanks.

Many roads require a weekly report of work, which corresponds, as to items, with the monthly report on distribution of work. As the month is a considerable portion of time this gives the office opportunity to keep in closer touch with the work which is being done, and, moreover, it serves to some extent, as a check upon the foreman's punctuality. For instance, a foreman, if he chose, could fill out the daily record of distribution of work for a whole month, by guesswork, at the end of the month, and yet the office might not be able to detect anything wrong. With weekly reports, however, he could not neglect this longer than a week, at farthest. In form this report is usually a summary of the work only, omitting the daily record of hours performed on each piece of work. Following are the usual column headings: Kind of Work—Amount of Work Done (The "No. of," "Cu. Yds.," "No. of Pieces," "No. Lin. ft.," etc., is indicated in writing)—No. of Hours—Cost of Work—Location of the Work—Remarks. I rather favor making this report every 10 days instead of every week. The weekly reports in the aggregate for each month must tally with the monthly report for the same month; that is, the monthly report must cover four "weekly" reports, the last of which, in each month (except February), sometimes covers 9 days and sometimes 10 days, thus making the fourth report in each month cover a considerably longer period than each of the other three, and with these inequalities it is not an easy mental operation to quickly compare the data of the four reports. Reports made on the evenings of the 10th, 20th, and last day of the month would cover periods more nearly equal in length. Weekly reports are usually made on the 7th, 14th, 21st and last day of the month.

In filling out the report for distribution of work there often arises a good deal of confusion and frequent mistakes over the matter of distributing the cost of the foreman's time among the various kinds of work performed. The clearest way of handling this matter is as follows: The foreman is paid by the month, with no allowance for overtime and no deduction made for time lost on account of bad weather, etc. Opposite his name in the time book (Form 1), in the column "Amount," will then appear the amount of his monthly pay, regardless of the time worked. Nevertheless, the actual time he spends with his men should go down on the time book, and he should make a correct distribution of his own time to the several labor accounts in the same manner as that of the laborers under his charge. In the item total hours for the month there will then be included the number of hours worked by the foreman. The item "total amount," less the foreman's pay, must then check with the product of two quantities, one of which is the total number of hours less the time actually worked by the foreman, and the other is the price per hour paid the common labor. In the distribution of work, whether the foreman engages personally in the work or not, his time spent with each kind of work should be charged to that item. Compute the cost for each item, according to the time recorded and at the rate per hour paid the common labor. Then to the item "General Repairs," or "Miscellaneous Work," add the difference between the foreman's monthly pay and the pay he would receive if he was paid for his actual time at the price per hour for common labor. In the case of a weekly report, use instead of the monthly pay one-fourth of it. This throws all the extra cost (over and above the price of common labor) of the part taken by the foreman in each piece of work into general repairs, and thus avoids the necessity of increasing the cost of each separate item pro rata for the time the foreman spent with it. This is really proper, because the additional amount which the foreman is paid above common labor is not necessarily because every piece of work he engages in actually requires his oversight, but on account of his general supervision of the section and for his responsibility. He also draws pay for Sundays whether any work is done or not. This additional amount therefore belongs properly to general repairs.

The time sheet and distribution sheet (Forms 1 and 2) have been filled out purposely to show this arrangement. It will be seen that on the time sheet the foreman is credited with 245 hours for the month. Subtracting this from 2218, the total number of hours, we get 1973 hours, which, at 12 cents per hour, gives us \$236.76; and this checks with \$286.76, the total amount, less the foreman's pay of \$50. This is clear and straightforward. Now on the distribution sheet the cost opposite each item is computed for the given number of hours at 12 cents per hour, the same as though no higher wages had been paid the foreman. The item "General Repairs" is 26 hours at 12 cents per hour, or \$3.12. Adding to this \$20.60, which is the difference between the foreman's pay of \$50 and his actual time of 245 hours at 12c. per hour, the total at the foot of the cost column (\$286.76) checks with the total at the foot of the time sheet. If the watchmen were paid a different rate from that of common labor, their time would have to be considered separately. Some divide the total amount by the total hours worked, to get a general average, which is the rate at which each item in the distribution of work is then charged. But evidently the time and pay of watchmen, flagmen, etc., should not be included in this average;

besides, there is with this method a good deal of cent splitting to be done, and the totals will not check exactly; and after all it does not seem as fair as the method above pointed out.

Some roads seek to get around this difficulty by instructing the foremen not to enter their time on the report of work distribution, leaving this to be done pro rata in the roadmaster's office at the end of the month. By this arrangement the time book and distribution report will check by leaving the foreman's pay out of consideration, and matters are simplified for the foremen, but the method of charging up the foreman's time to the various items does not seem to afford an equitable distribution. On some roads the foremen are relieved of all such "difficulties" by not being permitted to do any computing in the time books and other monthly reports. This is done by clerks at headquarters, so as to avoid errors which foremen "slow at figures" are liable to make. This plan is, of course, something of a reflection upon the foremen.

Some roads require that the time books and blanks for the distribution of time must be used for original entry; that is, that time and the distribution thereof must not be kept in a separate book or memorandum and copied into the regular book at intervals. Some roads also require foremen to carry these report books or blanks out on the work with them, so that they may be inspected by the roadmaster at any time. The purpose of rules of this kind is to prevent "doctoring" reports.

Tool Report.—The foreman's monthly report of tools is usually headed to show the number of tools of each kind on hand at the date of last report, the number received since that date, the number worn out or broken and returned during the same period, and the number on hand at the date of the report. Headings worded to correspond with such information are arranged horizontally across the sheet, as shown in Form 6, while the names of the various tools appear in the left-hand vertical column; or, as the list is a long one, the report is usually arranged in the form of a double-column sheet. The list includes every kind of tool in common use on track, and blank lines are left for writing in the names of special tools. A list of the tools in common use on railway track is given in Chap. IX, § 116. On some roads the monthly reports for tools and materials are combined on the same blank, one side of a long sheet being used for the tools and the other side for the materials. The following instructions are found on the tool and material reports of various roads:

Section and other foremen will be held personally responsible for all tools and materials in their charge, and will be required to make this report in full, and send to their division roadmaster, with the time sheet, at the end of each month.

All worn-out tools to be sent in for renewal must be plainly marked, giving the number of articles and the section to which they belong. Notice of number and kind of tools sent for renewal should be sent by letter at the same time.

Broken tools must be sent to the storekeeper.

The quantities reported must be ascertained by actual count and not estimated. Keep an accurate copy of each report.

When a foreman leaves the service of the company the roadmaster must

Railway.

TOOL REPORT FOR MONTH OF 189____ SECTION NO.

TOOLS	On Hand First of Month.	Received During Month.	TOTAL.	Used Up, Worn Out or Broken.		TOTAL.	ON HAND LAST OF MONTH.	CONDITION.
				Repairs.	Construction.			
Axes, Shimming								
" " Handles								
" Chopping								

Form 6.—Tool Report.

RAILWAY CO.

FOREMAN'S MONTHLY REPORT OF TRACK MATERIAL.

Section No. .... Division 189

MATERIAL	On Hand First of Month	Received During Month		Total	Used on			Shipped or taken by Work Train	Total	On Hand Last of Month	REMARKS
		Taken from Track	Other Sources		Repairs		New Work				
					[illegible]	Siding					
Rails, Steel, [illegible] lbs. per yd. Feet											
[illegible]											
[illegible]											

Form 7.—Material Report.

see that all tools and other company property charged against him are properly accounted for, and must examine his time books to see that all accounts are correct. When such is not feasible settlement for pay due him should be deferred until after the new foreman sent to take charge has checked over the old foreman's final reports on tools and material and forwarded the same to headquarters.

When a foreman takes charge of a gang he must receipt for all company property delivered to him by his predecessor.

Material Reports.—The usual column headings for the foreman's monthly report of material are as follows: Material—(In the next column to the right the "No. ft.," "No. Pairs," "Lbs.," "Lin. ft.," "Ft., B. M.," "Cu. Yds.," etc., or whatever term is necessary to designate unit of quantity is put down in writing)—On Hand First of Month—Taken Out of Track during Month—Received during Month—Where Received From—Used during Month (with the sub-headings "In Main Line Repairs," "In Side-Track Repairs," "In New Construction")—Shipped during Month—Where Shipped to—On Hand End of Month—Remarks. Under the heading "Material," in the left-hand column of the report, appear the names of the standard materials, or materials commonly used on the road, with blank spaces for writing in odd material not shown on the printed form. Form 7 is a sample head for a report of material. It is usual to classify steel rails according to length and the condition with respect to wear; iron rails, being now used only in side-tracks, are classified as "Of Use" and "Scrap." The following is an ordinary form of classification for steel rails, together with a list of instructions that is frequently printed at the bottom of the report of materials:

Classification of Rails.

First Class.—Whole rails that have never been in track.

Second Class.—Rails not too badly worn for main-track use, which have been taken out to make room for laying new steel continuously; also new or worn pieces of rail 14 ft. long or longer, fit for main-track repairs.

Third Class.—Rails fit only for use in side-tracks, if 3 ft. long or longer, and better rails in pieces from 3 to 14 ft. long.

Scrap.—Rails too badly worn for side-track use and all pieces less than 3 ft. long.

General Instructions.

All material reported above is supposed to be on hand and not in use.

All ties and timber reported as taken out of the track during the month, if decayed too badly for use again, should not be accounted for as on hand at the end of the month; but all other material taken out during the month, and not shipped, if not appearing on hand at the end of the month, should be accounted for in the "Remarks" column; for instance, broken splices, when thrown into the scrap pile, should be so accounted for.

This report must be made up by actual count of the quantity of material, and not by estimation.

As with the report on distribution of work, so with the report of materials, some companies require their foremen to fill out additional separate reports for special kinds of material received and used during the month, such as rails, ties, lumber, etc.

The foregoing remarks cover the reports usually sent in monthly or at other regular intervals. Besides these there are a number of forms or blanks in common use for reporting construction work, accidents and other occurrences, which are made out and forwarded as occasion requires.

Report on Rail Failures.—It is quite usual to take careful records of broken rails, or rails which fail irregularly in other ways, and the report form on rail failures on some roads calls for a great deal of detail information. Following are column or line headings that are used on the report blanks of various roads: No. of Rails—Length of Rail—Weight per Yard—Square or Miter End—Brand and Marks—Date Marked on Rail—Length of Time in Use—Cause for Removal—Nearest Mile Post (with the subheadings No., Direction and Distance)—Kind of Joint Fastening—Kind of Ballast—Which Track, North-bound, South-bound or Single—On East or West (North or South) Side of Track—Date of Breakage—At What Hour Discovered—By Whom—Broken on or off Tie—Was there any Sign of Flaw—If Broken, Give Length of Pieces—Which End was Broken, Receiving or Leaving—Approximate Temperature at Time Break Occurred—When had Track been last Patrolled—What do You Think was the Cause of Break—Was it on Curve or Straight Line—Condition of Track Surface 100 ft. Each Way from where Break Occurred—When Repaired—In What Way Repaired—What was Done with Rail Taken out—Label Number of Stored Pieces—Marks or Brand on Rail Put in to Replace Rail Taken out—Remarks. The blank for record of broken rails on the Burlington, Cedar Rapids & Northern Ry. has the following list of questions on the back:

Cause of Breakage.

Was break in cut?
Was cut well ditched?
Was track in good surface?
Were ties good?
What was the distance from center to center of ties at the break?
Were all the ties of same thickness?
Was track heaved by frost?
Was rail full spiked?
Was it a cut rail?
Was rail shimmed?
Had any of the shims worked out?
Do you think break caused by flat wheel?
What was the number and speed of train when seen?
What was track ballasted with? (Loam, Sand, Gravel or Rock.)
Was break on straight track or curve?
Was break on bridge or cattle guard?
Was break at fish plate hole?
Was train ditched?
What damage done?

The following instructions are commonly found at the bottom of reports on broken or damaged rails:

Instructions.

Section foremen will send this report to the roadmaster as soon as may be practicable after steel rails have been removed from track, and careful investigation has been made.

Be careful to report brand and marks correctly, and see that all information called for in this report is given for each and every rail taken up.

When two or more rails of the same length are taken up, on the same day (except in the case of rails damaged by wrecks or broken wheels) for the same cause, of same marks and brand, and whose histories are alike in every particular, they may be reported together by stating the number of such rails in column headed "No. of Rails," but when there is any difference whatever in the marks, brands or record, each rail must be reported by itself, on a separate line of the report.

A piece of rail about 12 ins. in length should be cut from the pieces each side of the fracture in broken rails. These pieces should be labeled and numbered so that they may be readily identified when it is desired to inspect the fracture at some future time.

This is a special report required for the purpose of identifying failures in guaranteed rails. The monthly report of materials must be made out just the same as though this report had not been made.

Report on Broken Splices.—The Lehigh Valley R. R. supplies its foremen with blanks for a monthly report of broken splices in main tracks. Following are the column headings of this report: No. of

Splices Taken out—Between What Mile Posts—Date When Put in Use—Inside or outside Splice—On Curves; High or Low Rail—On Straight Line—Open or Close Joint—Surface of Joint—Kind of Ballast—Weight of Rails per Yard—No. of Iron Splices—No. of Steel Splices (with the sub-headings "4 holes" and "6 holes")—East or West-Bound Track—Description of Break—Cause of Failure.

Report on Side-Track Construction.—Form 8 shows an ordinary blank for reporting labor and material in new side-track construction. The same form would also answer for new track construction of any kind.

.... R. R. Co.

..................DIVISION.

Report of New Side Track for .... *at* ....

Foremen must make out and forward this report as soon as the work is completed. The making of this report does not in any way affect the Monthly Report of Material. It is a special report, and all regular reports are made out just the same as though it had not been made.

Exact Location, Mile Post.......plus.......feet.		Material Used in the Co.'s Part.		Material Furnished for Private Part.	
		NEW.	OLD.	NEW.	OLD.
Steel Rail in Track......lbs. per yard,	Feet.				
Iron " " ...... " "	"				
" Guard Rails,	"				
Splices, Angle Bars,	No.				
" Fish Plates,	"				
Splice Bolts,	"				
Nut Locks,	"				
R. R. Spikes,	Lbs.				
Cut "	"				
Rail Braces.	No.				
Cross Ties, first-class (what kind),	"				
" second-class,	"				
Switch Timber,	Lineal Feet				
Frogs, Kind, No. of Frog,	No.				
Switches, "	"				
Switch Rods,	Sets				
" Stands, "	No.				
Ground Levers, "	"				
Headshoes. "	"				
Crossing Plank,	Feet, B. M.				
Stop Blocks,	Complete Pairs.				
Bunting Posts,					
Ballast, Kind and Quantity,					
Length of each part,	Feet,				

	Foreman No. Days.	1 Man No. Hours.	Cost.	Foreman No. Days.	1 Man No. Hours.	Cost.
Labor, Grading, Track Men.						
" " Work Train,						
" Laying, Track Men,						
" " Work Train,						
" Ballasting, Track Men,						
" " Work Train,						
" Taking Up Track, Track Men,						
" " " Work Train,						

Total length of track from headblock.........feet. Total length of track in clearance.........feet.

Completed........................, 190.. ....*Foreman, Sec. No*........

Correct,.... .. ..*Roadmaster*.

Form 8.—Report of New Side-Track Constructed.

Report on Structures.—With a view to keep informed on what is being built along the line of the road adjacent to the track, as well as to obtain a record of all structures built on the right of way, it is usual to have a report blank to cover the information desired. Form 9 is a sample of such a report.

............R. R. Company.
..................................Division.

REPORT ON STRUCTURES ADJACENT TO TRACK.

TO SECTION FOREMEN:

No structure shall be erected upon the company's property without the written consent of the superintendent. You must report to the roadmaster any violation of this order.

In all cases of New Buildings, Fences, Platforms or any structure whatever, commenced on your section within———— feet of the center of the main track, you are hereby required to furnish the information, as noted below. Fill up one of these blanks and forward it at once to the Roadmaster.

1. **Name of party building,**
2. **What is he building?**
3. **Distance from Center of Main track or Side-track; say which, or give both.**
4. **On which side of Track.**
5. **Name of nearest Station.**
6. **Distance East or West of said Station.**
7. **No. of Lot (if in a town).**
8. **Who gave Right of Way to R. R. Co.?**
9. **Any other general information.**

.................................., **Foreman.**
Section No.........

Form 9.—Report on Structures Adjacent to the Track.

Report of Stock Killed or Injured.—Reports of stock killed or injured are made by the conductor and engineer of the train which strikes the animals, and also by the foreman of the section where the accident takes place. On some roads, however, the report blank for this purpose is filled out by the station agent, from the verbal report of the foreman. The agent is supposed to repeat the questions printed on the blank and then write down the replies of the foreman. Both the agent and the foreman then sign the report. When stock cannot be buried at the point where it is killed it sometimes costs a good deal to remove the carcass to another point. One cheap way to dispose of killed stock, if the material is at hand, is to pile old ties or other waste wood on the carcass and burn it. On some roads such work is attended to by the track-walkers. Form 10 is a report blank with the questions used by various railways regarding the particulars of accidents to stock struck by the trains, followed by the usual instructions to section foremen.

..........RAILROAD COMPANY.

SECTION FOREMAN'S REPORT OF STOCK KILLED OR INJURED.

To..
Division Superintendent,
at...........................

On section No............*on the*...................*day of*...........190...
about........ *o'clock*....*M., Train No*........*from*..........., *Engine No*.......
struck and..........................*the following stock*:
What kind?.....................*Number and Color?*..........................
Brand or Mark? (*very important*)..

Was the stock allowed by the owner to run at large?............................
At what place was it struck? (Give name of and distance to nearest station.)........
Was it north, south , east or west of this station?...............................
Was it in a cut, on a curve, or where there was a clear view of the track?..........
Was it struck within the switch limits of station?...............................
Was stock struck on either a public or private crossing?..........................
Was the highway located straight or diagonally across the track ....
Was it struck within the limits of an incorporate city or town?....................
If so, what was the speed of the train?..
If so, give name of same...
If on private crossing, when did you last see gates?..............................
Were the gates then closed?......*Was the track fenced at POINT where the animal GOT UPON the track?*........
What is hight of fence, in feet and inches?.......................................
Of what material is fence? How many wires or boards?..........................
In what condition and how old is fence?...
If in good order, how did animal get on the track?..............................
If out of repair, state in what particular, and how long it had been so, and your reasons for not repairing it ....
Are all the cattle-guards near that point in perfect order?......*If not, why?*.......
What is the distance from cattle guard to cattle guard? ....
Give size and depth of cattle guards ....
If possible, describe place where animal got onto track, and how..................
Were any of the section men in sight?..
What did you do with the animal, after the accident?............................
Did you take the hide?...
What did the owner do with the animal, after the accident?.......................
What amount, if any, did owner derive from sale or use of carcass or hide? $......
How much did you receive for carcass? $......... *How much for hide?* $........
Estimated age of animal?..................... *Estimated live weight?*............
Estimated CASH VALUE before accident, $..........*(This estimate must be made independent of owner's statements.)*
Owner's estimate of value of the animal at the time, if he expressed himself on this point?........... $
If not killed, state the extent of injuries.......................................
If only injured, state amount of damage $...
Owner's name, occupation and residence, if they can be ascertained...............
.........................*Owner's post office address*...........................
How soon after the accident did the owner know of it?...........................
Who informed him?............. *Was the animal in charge of any person when struck?* ....
If you know of any persons who witnessed the accident, give names, residence and occupation ....
Names of owners of land on each side of right of way where animal was killed. (Spare no effort to answer this question correctly.)...................
....
State here any particulars relating to the accident, not asked for above, which you consider the claim agent ought to know.......................................
....
....*Section Foreman.*
This report is made at....................
Date............ ....,190....

Instructions to Section Foreman.

You are required on the same day you learn that any stock has been killed or crippled on your section, to fill this blank with the information required, and deliver the same to the Station Agent, to be forwarded by first train to your Division Superintendent. Be particular to answer the questions correctly. Make no statements that can be truthfully contradicted.

When stock has been injured on your section, if possible, notify owner, and request him to take charge. Assist him in removing crippled stock if he requests it. When stock is struck on a public crossing or on station grounds you should first notify the owner to take care of his property, as the company is not liable for stock struck at such places, but in case he refuses the animal should not be skinned, but buried with hide on. When cattle are killed and the owner cannot be found, or will not take possession of the animals, sell the meat to the best advantage and give the cash proceeds to the agent or remit with letter of explanation. Salt all hides immediately and thoroughly as soon as removed from stock.

When animals are injured by having their legs broken, or otherwise wounded so as to be past recovery, they should be slaughtered and sold to the best advantage for the company, and proceeds of sale handed to agent.

Keep a correct record of the brands and marks.

When a number of animals belonging to different persons are struck at the same time and place, make separate reports relative to the property of each owner.

In case the animal or animals are removed before you are informed of the accident, you must report all the information you can obtain in reference thereto, as required within, giving names of informants.

You are expected to acquaint yourself with the value of different kinds of stock, so that your estimate of damage will be correct. Guard against placing values too high or too low.

You are requested not to state to the owner your opinion as to what proportion of the value of stock will be allowed by the Company, or to admit any liability under any circumstances.

Inform owners of stock killed that to insure a prompt adjustment of their claims, they must communicate direct with the general claim agent at..........

......................, Superintendent.

Form 10.—Report of Stock Killed or Injured.

Fire Reports.—Section foremen are expected to make a report of all fires that start along their sections, when property is destroyed, whether in their opinion the company is liable or not. Careful investigation should be made concerning the origin of such fires and the progress of the same, and, particularly, whether reasonable effort was made to put the fire out or stop its progress. Form 11 is the usual blank for reports on losses by fire.

...........RAILROAD COMPANY.

SECTION FOREMAN'S REPORT OF FIRE LOSSES.

Immediately after a fire, the Foreman of the Section where it occurred must notify the Division Superintendent, by telegraph, of the fact, and then fill out this blank and send it to him by FIRST TRAIN. If several pieces of property are burned, make a separate report for each owner.

To....................................

Division Superintendent,

at ....

A Fire started on Section No.......on the......day of................190....

Questions to be Answered by Section Foreman.

Name and residence of owner of the property destroyed ....

Name of tenant, if rented ....

About how far from the property burned did the fire originate?..................

Was the property located upon land owned by the Railroad Company?............

Give name of the nearest station............Post office address of owner..........

Was it north, south, east or west of this station?......How far from station?......

EXACT time of day or night fire started...

Origin of fire..

Distance from center of track to place where fire started............feet..........

Width of right of way........................

Did the fire start on the right of way?..........Which side of the track?..........

Condition of right of way (What combustible material)..........................

Had right of way been mowed, burned or cleaned off?.......If so, when.........

If not, why?...

What was the extent of the fire?...

Distance from center of track to property destroyed...........................

What had owner done to protect his property from fire?.........................

Did owner assist or furnish assistance in putting out the fire?................

Was wind blowing high or low?..........From what direction?................
Were there other fires in the same neighborhood at the same time?...............
If so, give the origin of these fires...
Did other parties lose by the same fire? If so, give their names. (Important.)
....
Who was first at the fire?...
Was fire caused by section hands?...
What was exact time last train passed?..........What was No. of train?..........
Was it a passenger or freight?...................... If you know the fire was set by an engine, give the number and state the facts leading you to believe that it was set by such engine ....
....
How soon after the fire started did you get to it?...................................
Did you or your men assist to put out fire?...

Description of Property.

....
....
What is your estimate of loss? $..... If fence, how many boards or rails high?.... No. of panels burned..........No. of posts..........If meadow or pasture, number of acres..............Kind of grass............If standing grass, give number of acres............Hight of grass..............Kind of grass..................
If trees, give number........kind..........age..........approximate hight...... and whether burned all around or on one side, and on which side..........
If hay, number of tons. (Give length, breadth, number and approximate hight of stacks)........Price per ton at nearest market at time of fire, $......(Important). If straw, what kind..........Length, breadth, number and approximate hight of stacks) ....If grain what kind...........Number of stacks................ Dimensions of stacks..............Number of shocks..........Number of bushels (threshers' measure)..........Price per bushel at nearest market on day of fire, $..........Had there been any recent rains, or was it dry? .... Give the names and addresses of all witnesses of the fire...............................
....
How much is the owner's claim for damage?..
If the building belonged to the Company, what kind? ....
Used for what purpose?...
Dimensions...
Contents...
Extent of damage...
If wood, state space burned over ....
Kind of wood .... Amount in Cords ....
If ties, kind and number ....
If piles, kind, number and length ....
If piling, extent of damage ....
If bridge, number, kind ....
Extent of damage ....
Estimated cost of repairs or replacing, $..

Give any particulars here that you have not incorporated in answers to above questions, which you think will be of service to the Company.

....
....

...............................Foreman of Section No......

This is made from.............................

Date..................190....

Form 11.—Report on Fire Losses.

Casualty Reports.—Section foremen are expected to report to the roadmaster, by wire, every case of derailment to engines and cars on their sections, and injury of any kind to persons, no matter how trivial, as the result of such derailment, or injury happening to any person on the track in any manner. This includes people injured at road crossings, and employees hurt on hand cars and in other ways. In case of injury to persons the name of the person is given and the nature of the injury. As soon thereafter as he is able to do so the foreman must write out the full particulars and forward the report promptly. The reports of derailments should be filled out as fully as the information can be obtained, and these should be retained by the roadmaster in convenient shape for future reference, in case he is called upon to defend the track against the reports of the train men. Form 12 is a sample of a casualty report blank.

............................Railroad Co.

..............................Division.

SECTION FOREMAN'S CASUALTY REPORT.

No. ....

Section No. ......

Date of accident..........190... *No. Train*....... *No Engine*........ *Time*.....
Engineer .... *Conductor* ....
Section Foreman ....*Location* (*distance from nearest station*) ....

Injury to Company's Property.

Under this head report all accidents to trains resulting in any damage or loss to Baggage, Freight, Cars, Locomotives, Track, Bridges, Buildings or other property. State the amount of damage, the nature of the accident, how caused, what action was taken after accident to protect trains and prevent further damage, and what was done towards repairing damages and placing track in order.

....
....
....

Details.

Nature of accident...
Cause..
Result...
Main, side or private track.................*At switch or frog*...................
On straight line or curve, and what was degree of curve, elevation and gage?
....
At what rate of speed was train moving at time of accident?...................
Were proper signals given?...
Damage to track,etc..
Cost of material.......................*Labor*...............................
Cost of wrecking done by trackmen..
Remarks ....
Was track obstructed by accident?...........*How long?*.....................
On what section?......*Was engine or cars off track?*....*No. of cars off track*......
Was a report sent to you, and by whom?........*At what station was it left?*.......
Was the accident at a Road Crossing?..........*Was the track in good condition before the accident occurred?*........

Injury to Persons.

Under this head report every accident to Employees, Passengers or other persons. Use a separate blank for each case.

Name...
Residence,...
Occupation...
Employee, Passenger or other...
Nature and extent of injury..
How caused...
Name and Residence of Witnesses..
....
What disposition was made of the injured person?..........................
What was done with the personal effects and papers belonging to injured person?
....

Signed...................,Foreman.

Form 12.—Casualty Report.

Extra Gang and Work-Train Reports.—It is customary for the foremen of floating gangs, extra gangs, and other parties of men doing work upon

RAILWAY CO.

FENCES REBUILT AND REPAIRED.............................DIVISION.

Month of..............................189 .

[illegible]	Land Owner	New Wire Fence					New Board Fence				Board Fence Repaired				Wire Fence Repaired				Side of Track	Remarks
		Line Feet	No. Posts	Staples	Wire Used	Labor	Line Feet	Feet B.M.	No. Posts	Labor	Line Feet	Feet B.M.	No. Posts	Labor	Line Feet	Wire Used	No. Posts	Labor		

Form 13.—Fence Report.

RAILWAY COMPANY.

......................................DIVISION.

DAILY REPORT OF CONSTRUCTION TRAIN SERVICE..............................189 ...

No. of Train	Men on Train		Time Arrived at Pit	No. Cars Loaded on Arrival	Time Left Pit	No. Cars in Train	Time Arrived at Dump	Nearest Mile Where Dumped	Time Left Dump	Time Delayed	Cause of Delay
	Brakemen	Laborers									

No of Engine..................

Engineer

Fireman.................. Conductor

Form 14.—Work-Train Report.

the right of way that is provided for in the section foreman's blanks, to use the same blanks as the section foremen. Form 13 is a common style of blank for a fence report. Form 14 is a common style of blank for a work-train conductor's report, and the following is another:

DAILY REPORT OF WORK DONE BY WORK TRAIN.

Date.................................190..

Number of Cars Dirt or Ballast Unloaded..............................

Where Unloaded ....

Other Work Done..............................

Number of Engines Used.............

Men Employed.

Foremen .... Flagmen ....

Engineers .... Trainmen ....

Firemen .... Laborers ....

Conductors ....

Time Worked by Pit Engine ....Hours..............Minutes.

Time Worked by Road Engine................Hours..............Minutes.

Amount of Coal Used by Pit Engine..............................Tons.

Amount of Oil Used by Pit Engine..............................Gals.

Pit Engine Detained..........................Hours..............Minutes.

Cause ....

Amount of Coal Used by Road Engine..............................Tons.

Amount of Oil Used by Road Engine..............................Gals.

Road Engine Detained........................Hours..............Minutes.

Cause ....

....Conductor.

Form 15.—Work Train Report.

It is also well to observe that in the work train foreman's daily report (or conductor's report, if he acts as foreman) it is usual to require a report of each car and what was done with it. Following are the usual column headings: Car No.—Whose—Loaded (when taken)—Empty (when taken)—Where Loaded—With What Loaded—No. of Cu. Yds. or Pieces—Weight—Amount—Where unloaded—Where Left (with the subheadings "Loaded" and "Empty"). The "Remarks" column is headed as follows: "Work-train foremen will make a brief statement in the space below, noting all delays and explaining the cause, with any other remarks of a special character." At the bottom the blank is ruled and headed for a summarization of the work performed, as follows:

Engine No ....Engineer ....Conductor..............
Laid over last night at...............Started out at..................a. m.
Quit Work at........p. m. Weather during the day.........................
Lying over to-night at..................................This report was made out at ....p. m.

Summary of Work Done.

No. Car-Loads Iron Rails hauled....	No. Cu. Yds. Ditching done..........
No. Car-Loads Steel Rails hauled..	Lin. Ft. Ditching done..............
No. Car-loads Dirt hauled..........	New Rails Laid, Lin. Ft. track......
No. Car-Loads Crusher Screenings..	No. Ties Put in.....................
No. Car-Loads Gravel hauled........	No. Men Employed.................
No. Car-Loads Stone Ballast hauled.	Total No. Hours on Time Book....
No. Car-Loads Ties hauled.........	Hours Consumed in Running (Train)
No. Car-Loads Wood hauled........	Actual Time Worked (Crew)......
No. Car-Loads Rip-Rap hauled......	

OTHER WORK.

Kind of Work.	Where.	Amount of Work.			Hours for One Man
		Lin. Feet.	No. Pieces.	Cu. Yds.	

Total..................

Foreman...

All work done whatsoever must be reported above, and the time must be strictly accounted for. Work for which headed lines are not provided must be described under "Other Work."

Form 16 is a common style of steam shovel report blank. In most cases such reports are made and forwarded daily to the roadmaster or engineer in charge of construction.

..............Ry. Co.

DAILY REPORT OF WORK WITH STEAM SHOVEL NO......

Date..............190..

Where Working	Number of Laborers...............
Number of Cars Loaded............	Amount of Coal Used ....Tons.
Cubic Yards Per Car..............	" " Oil " ....Gals.
Time Worked....Hours....Minutes.	Kind of Material....................

Detentions.

Waiting for Cars......Hrs....Mins	Fixing Track ....Hrs....Mins.
Moving Shovel ....Hrs....Mins.	Bad Weather ....Hrs....Mins.
Repairing Shovel ......Hrs....Mins.	Other Causes ....Hrs....Mins.

.... Foreman.

Form 16.—Report of Steam Shovel Work.

Following are the column headings for the ordinary monthly report of ballasting done, to be filled out by the section foreman: MAIN TRACK between Mile Posts (—and—)—No. of Ft.—Depth in Inches—Kind of Ballast—SIDINGS—Location—No. of Ft.—Depth in Inches—Kind of Ballast. Form 17 is the ordinary style of blank for a tie inspector's report.

Form 18 is a blank requisition for supplies, with a receipt attached. The instructions which appear upon the blank explain the systematic manner in which it is used. On most roads practically the same form of requisition blank is used by all departments. In the track department the foreman fills out the blank for supplies desired and forwards it to

REPORT NO.

RAILWAY CO.

MAINTENANCE OF WAY AND STRUCTURES DEPARTMENT.

REPORT OF TIES TAKEN UP AT .... DATE .... 189..

CONSIGNED TO .... AT ....

BY WHOM DELIVERED.	CAR. INITIAL.	CAR. NUMBER.	NO. TIES.	CLASS.	KIND OF TIMBER.	DIMENSIONS.	REMARKS.
TOTAL NO. OF TIES.							

APPROVED,

ROADMASTER.

I HEREBY CERTIFY THAT THE ABOVE MENTIONED TIES HAVE BEEN DELIVERED AND INSPECTED AND THAT THE NUMBER AND QUALITY AS STATED ARE CORRECT.

TIE INSPECTOR.

Form 17.—Tie Inspector's Report.

the supervisor or roadmaster, who passes upon it, scrutinizing the items carefully for unnecessary requests. In cases he may find it advisable to make alterations, or he may withhold it from issue pending an explanation from the foreman concerning the need of certain articles ordered. He then forwards it to the storekeeper or to higher authority for approval. Foremen are usually instructed to send in their requisitions on the first of the month, or at appointed times. This order is not, of course, supposed to cover supplies needed in haste. In such cases the foremen frequently order from the roadmaster by wire, requesting immediate shipment. For such sudden calls the roadmaster usually keeps at headquarters, independently of the storekeeper, a small stock of the different patterns of frogs, switches, etc., quantities of fastenings and other commonly needed supplies, neatly arranged on skids or platforms conveniently located for loading into baggage cars when the urgency of the situation requires such things to be forwarded by passenger train. Where considerable quantities of supplies are needed, as in new construction, it saves a good deal of labor and unnecessary handling to have them shipped from the manufacturer direct to the point of use.

Foremen should read carefully the instructions on all reports with which they have to do, and try to get a clear understanding as to how it is desired they should be filled out; and try to answer in a direct and clear manner all questions asked. Information relating to the matter of any

Detroit, Grand Rapids & Western Railroad.

TRACK DEPARTMENT

________ Station ________ 189_

** ________ Requisition for Stores

Send to Section ________

QUANTITY	FULL DESCRIPTION OF ARTICLES WANTED	VALUE	
CORRECT	SUPT. TRACK		

Sign when ordering

**Here say "Ordinary" or "Special" as required.
Make out requisitions on first of each month and send to Sup't Tracks

Approved ________ *Gen'l Supt.*

Detroit, Grand Rapids & Western Railroad.

TRACK DEPARTMENT.

________ *Station* ________ *189*__

Received of Store Department the following articles, in good order

by Section ________

QUANTITY	ARTICLES

Sign here when goods are received.

Fill out this sheet to correspond with order, when ordering.
This sheet will be returned when goods are shipped. When signed send this to

SUPT. TRACKS, Grand Rapids, Mich,

Form 18.—Requisition for Track Supplies.

report, which is not provided for by a headed line, or by a place for "remarks" or otherwise, should, if the foreman thinks it of importance, be written on a separate slip of paper and pinned to the report, the foreman signing his name thereto. It is a good plan for foremen to retain duplicates of such reports sent in as include the heading "On Hand at Last Report." It is usual to furnish each foreman with two copies of time rolls, tool reports and material reports, so that he may retain a copy of each report sent in. Another plan is to send the foremen their blanks for the succeeding month in time to copy off such data as will be necessary to start the new report, before the report of the present month is sent in. It might also be arranged to supply the foremen with sheets or blanks for duplication of pen writing. In still other cases the roadmaster's office, in sending out the new blanks each month, fills in the column calling for the quantity on hand at last report. It is also convenient for the foreman to retain duplicate copies of requisitions sent in, and on some roads the requisition blanks are arranged for duplicating by the insertion of a carbon sheet. Blank books of pocket size with pages ruled for distribution of work should also be furnished the foreman for convenience of taking note out on the road when the work is performed. He can then copy from this to the regular reports sent in and be able to give the information with greater accuracy than otherwise; for duties will so press a foreman day and night, at times, that he cannot afterwards recall just how all the work was divided. This book he may retain for his own reference, and very convenient he will often find it, too. Changes of foremen or transfers from one section to another, except, of course, in emergencies, should be made at the beginning of a month, so that the man in the new place may start his reports even with the month; otherwise there is a splitting of reports.

The reports required of roadmasters by the higher officials usually call for summarized accounts of the items embodied in the reports of distribution of work from all the section crews, yard gangs, floating gangs, and work-train foremen, together with work performed at wrecking, his office and store-room expenses, tool repairs, etc.; also a report giving the sum total of the tools and track materials received, used, and accounted for at the end of the month, for his division. In other words he makes up an office record giving the total expenditure under each account for the division, for each month of the year, with the average annual cost per mile for each account. Such reports are made to the superintendent, engineer of maintenance of way, or chief engineer, according to the organization of the maintenance of way department. The roadmaster may also be called upon to fill out special blanks specifying all changes in the physical condition of the road and right of way during the month, such as new track built or track taken up, new rail laid, new ballasting, new fence built, etc., and the location of each piece of work; all of which may be gathered from the reports of his foremen. Labor and materials chargeable to maintenance and new construction are of course kept separate. Forms for such reports are similar to those used by the foremen.

Another system that comes highly recommended is one whereby all labor and material reports are digested and summarized in the office of the general roadmaster or engineer of maintenance of way. At appointed intervals, usually every month, the track foremen make their reports to the roadmaster or supervisor, who carefully examines them, giving his approval, if correct, and then passes them on to the general officer of the track department. Before forwarding these reports, however, he makes up an office record of all material on his division and of the total expenditure of labor and material under each account; this to be retained in his office for reference. In the office of the engineer of maintenance of way or general roadmaster the force of clerks consolidate the different section reports for each division into one summarized statement for the division. One of the advantages claimed for this system is that it reduces the clerical work of the roadmaster's office to a minimum, giving him more time to devote to the field than would otherwise be the case.

On some roads the engineering department requires yearly a permanent record of the right of way and all property and structures thereon. The blanks are made to be filled out by the section foremen, and are headed to show the "Number, Length or Amount at Last Report"—"Added Since Previous Report"—"Removed Since Previous Report"—"Remaining at this Report"—Remarks. The left-hand column is worded to show the amount of all kinds of railway property, such as the number of miles of main, single and double track, the number and total length of sidetracks, measured between frogs; the length and kind of fence, number of railway and highway crossings, the number and kind of frogs, switches, cattle guards, culverts, stock pens, number and kind of dwellings, tool houses, sign boards, mile posts, water stations etc.

Correspondence.—Correspondence between railway officials and their agents or employees, known as "railway mail," is carried in the baggage service. Such matter is usually marked "R. R. B." (Railroad Business) or "R. R. S." (Railroad Service) and is supposed to relate strictly to the business affairs of the company, private correspondence being forbidden by the regulations of the postoffice department. Foremen should keep well posted as to the wishes of the roadmaster regarding all matters between them, and when doubt arises they should write and find out, and not delay a week or more waiting for the roadmaster to come around, or try to catch him for a moment on some train while stopping at a station, when, as usual, there will be a number of matters to engage his attention all at the same time. In cases of emergency they, of course, communicate by telegraph. When questions are asked by letter it is a good plan to write the answer on the reverse side thereof, or on a separate piece pinned to the question, so that the question may be returned with the answer. This saves stating the question over again in the answer and may make the answer more understandable; for where scores of notes are sent out every day from the office it cannot be expected that all can be remembered, and it is too much trouble to take copies of the least important ones. Foremen should be prompt in answering all correspondence with the headquarters and in forwarding their reports. If practicable they should be sent by the first train after the time arrives for the reports to be closed. The same promptness should be observed at the headquarters in corresponding with the employees.

The practice of using the telegraph service for transmitting information between the employees and the heads of the various departments is quite commonly abused to such an extent that the wires are overburdened with work, and delay in the transmission of messages of importance is the result. It frequently happens that a message filed after 4 p. m., which would not ordinarily receive attention or be answered before the next morning, can be sent by train mail and reach the destination early enough during the night or early enough the next morning to secure the desired result, if special attention be given to such messages by the employees handling the railway mail. To relieve the telegraph wires of messages of this description a number of roads have adopted the use of the so-called "pink

From .... by Train No. ...... Date ....

R. R. B.

AGENTS AND TRAIN BAGGAGEMEN.

WILL BE HELD PERSONALLY RESPONSIBLE
FOR FAILURE TO GIVE THIS

SPECIAL AND PROMPT ATTENTION

THE CEDAR RAPIDS ROUTE

THIS ENVELOPE MUST BE USED FOR **TRAINGRAMS** ONLY

ALL TELEGRAMS NOT FILED FOR TRANSMISSION BEFORE 4.00 P. M. TO WHICH REPLY IS NOT REQUIRED BEFORE THE FOLLOWING MORNING WILL BE FORWARDED BY TRAIN MAIL WHEN ADDRESSED TO POINTS WHICH CAN BE REACHED BY TRAINS AT OR BEFORE 8.00 A. M. ON THE FOLLOWING DAY.

Form 19.—Special Envelope for Prompt Transmittal.

envelope" or "traingram." This scheme simply provides an envelope which by its color plainly indicates the character of the message enclosed, so as to insure special attention at the hands of the baggage men and other employees concerned in the prompt delivery of such mail. Form 19 is a reproduction from one of these envelopes.

195. Track Inspection.—This subject brings us to the dress parade part of railroading. The kind of inspection that is considered on previous pages refers principally to observation of the condition of the track with respect to its safety for the passage of trains, whereas the object at present in view is to consider methods and means for examining track more especially for the purpose of comparing its condition and the surroundings with established standards or with ideals. Track may be inspected for such a purpose in two ways—by observation and by mechanical devices or recording instruments. The most thorough manner of inspecting track by observation is to walk over it and look closely into all the details which affect its condition; but such is necessarily a slow process, and such thoroughness is not desired for all the purposes for which track inspections are made. For most purposes it answers well enough to note the condition of things as they appear from a moving train, the smoothness of the track being judged by the riding of the cars. On many of the railways of the country, especially on some of the large systems, the track is inspected annually by the chief officers of the road, in company with the maintenance-of-way officials. Such inspections are nearly always made by observation from trains, for the purpose of comparing the general condition of the track and company property with that of other years, or to award prizes to the various grades of petty officials whose track is found in the best condition. On such occasions it is customary to appoint committees to carefully observe and mark the several details or features which determine the standing of each section of track. To be worthy the name of an "inspection of track" the trip must be systematically conducted—something more than a mere pleasure excursion, where the inspection party occupies the rear end of a finely upholstered observation car to gaze out upon the track through a haze of cigar smoke, at occasional intervals between stories.

The usual arrangement for conducting an annual inspection of track is to seat the marking committees at the open end of an observation car having the seats arranged in tiers, sloping back from the end of the car. In some instances an outfit is improvised by placing seats in a box car with an end knocked out, while some companies have a coach with a glass front or end, permanently fitted up for the purpose. The observation car is sometimes placed at the rear of the inspection train and at other times, and preferably, it is the practice to push it at the head of the train, giving a better opportunity for close observation of things. Such inspections are usually made during the fall of the year, after the winding up of the renewals and other important work of the season. The marking committees are supposed to take note of those conditions of the track which stand in relation to the labor performed upon it and the supervision thereof, such as line and surface, gage, level, elevation of curves, tightness of bolts and the general condition of the joints; the dressing of the ballast and shoulders, spacing and alignment of ties, the working condition and alignment of frogs and switches; the general condition of side-tracks and fences; the neatness of the track and right of way respecting the cutting of grass and weeds, and all such matters as come under the head of policing; the neatness of station grounds, section houses and yards, and tool houses; drainage conditions, which involve the condition of ditches and culvert ends; the condition of highway crossings. Where the awarding of prizes is involved in the inspection it is also customary to take account of the expense of maintenance, and on some roads also the number of failures of signal lights reported, accidents on account of defective track, including side-tracks; obedience to orders, general attention to duty, and accuracy in making reports.

In the practice of some roads each member of the inspection committee is supposed to take note of all features on which ratings are desired, and mark accordingly, but more usually the work of the committee is systematized, so that one man, or sometimes two men, are appointed a sub-committee to mark for each feature, being supposed to confine the attention to the single feature or detail. Thus, in the inspection of track for alignment, it is usual for the sub-committee on that feature to take a position directly over one or both rails, each member confining his attention solely to one rail. In the inspection of track for surface the inspector takes a position as far to one side of the car and as low down as he can get, so as to be able to catch the surface outline of the opposite rail to best advantage. He then devotes his attention entirely to that rail. Switches are inspected by stopping and making careful examination of the parts and their adjustment and of the alignment of the main track and turnout lead. For testing the gage of the track the engineer is signaled at random to stop, and this is sometimes done several times on each section. The level of tangents is tested by a level indicator on the car or by leveling across the rails when stopping. Stops are also made at curves to test for gage and for curve elevation.

The usual speed of an inspection train is 12 to 20 miles per hour—more frequently the latter speed. In some cases it is the practice to first run the inspection train over the track at high speed, in order to find the irregularities in line and surface to best advantage, and on the return trip to run at slow speed and take close observation of the condition of the ballast, ditches, culverts, switches, policing, etc. On the Pennsylvania R. R., where the managing officials have always laid stress upon an annual inspection of track, the inspection of the main line between New York and Pittsburg is a somewhat elaborate affair. The general manager, all the general superintendents, the general superintendent of transportation, general superintendent of motive power, superintendent of telegraph, principal asst. engineers, superintendents of motive power, general agents, division superintendents, chief engineer of maintenance of way and assistant engineers take a train in New York in the morning, run through at the rate of about 40 miles per hour, arriving at Pittsburg in the evening. The next morning the party, which now takes in the supervisors and assistant supervisors, is split up into four or five train-loads, which start back toward the east inspecting matters in detail, a whole day being devoted to each of the four superintendent's divisions between Pittsburg and New York. The marking committees are five in number, as follows: Committee No. 1, on line and surface; committee No. 2, on freight tracks and sidings, frogs and switches; committee No. 3, on ballast, joints and tie spacing; committee No. 4, on ditches, road crossings, station grounds and policing; committee No. 5, on telegraph lines and fixed signals. The whole party, which numbers about 200 men, is divided among the five committees, each class of officers being represented on each committee. On branch lines and on the Lines West of Pittsburg the general inspection does not take place every year.

On the Louisville & Nashville R. R. the duty of inspection is divided between five committees of one member each, and in addition a "revisory" committee composed of two members, all of whom are appointed by the chief engineer. The "five committees" are seated in the rear row of seats of the observation car at the rear of the train, positioned from left to right as they would appear to one standing in the car and looking toward the rear, as follows: Committee No. 1, on line and surface; committee No. 3, on spiking, switches and sidings; committee No. 5, on station grounds and policing; committee No. 4, on ditches and banks; committee No. 2, on joints and spacing of ties. The two members of the revisory committee sit in the middle of the next row of seats. The office of the revisory committee is "To interpret the instructions and specifications governing the annual inspection; to give a general supervision to the inspection, watching the work of all the inspectors as far as possible, and from time to time to check the markings of the different committees. If both members of the revisory committee agree that any committeeman is marking too high or too low, they shall instruct such committeeman to correct his marking accordingly, and their instructions shall be obeyed. An appeal may be made to the revisory committee from the markings of a committeeman." The car has a glass end extending over the rear platform, with seats arranged in tiers, so that those sitting on the back seats can see over the heads of those in front of them. In front of each member of the inspection committee there is a series of electric push buttons connected with a number board near the top of the car, the numbers on the board corresponding to those on the buttons at the service of the inspectors. The number boards are plainly visible to all sitting in the car, so that the rating of each committeeman on each mile can be seen by all present. The committees are composed of roadmasters and superintendents who have been roadmasters, with exception of committee No. 5, who is usually a superintendent. The revisory committees are selected from roadmasters or superintendents who have been roadmasters, and who are considered to be the most experienced men available.

On this road the committee on line and surface occupies a position directly over one rail and inspects that rail for line and the opposite rail for surface. Perfect surface requires that the tops of rails be level transversely on tangents, except at the entrance to curves, uniform elevation of outer rail on regular curves and elevation varying with curvature on spirals. Short sags, within a space of ten rail lengths, are counted as irregularities. When repairs to bridges or trestles, or other work requiring trains to run at a less speed than ten miles per hour, are being made, such piece of track is not considered in the marking. In the inspection of joints points are counted off for the following irregularities: missing bolts, missing spikes, joint out of line, joint out of surface, joint ties not properly spaced, improper allowance for expansion in the rails. Spikes must be driven straight and have a proper bearing against the flange of the rail. In the rating for spiking marks are counted off for spikes missing, spikes not driven down, and for improper position of spikes. In the rating for switches and sidings marks are counted off for headblock not properly banked, point rail not fitting snugly against stock rail, rattling of frog or switch, stock rail badly worn or bent, lead of switch not symmetrical, guard rail not in accordance with standard plans, siding not to proper grade, bad line and surface, space between tracks not filled level with tops of ties, targets of switch stands not parallel with and at right angles to the track or for colors not bright. In the rating of ditches and banks points are marked off for roadway less than standard width, imperfect slope of embankment or cut, edge of ditch or fill not parallel with the rail, embankment supported by old ties or timber, imperfect drainage on embankments or in cuts, imperfect berm at foot of fill, lack of surface ditches, imperfect sod line, bad surface of roadbed. In the rating on policing points are marked off for failure to cut right of way, old ties scattered around, rubbish not burned, unsightly holes dug in the right of way, water standing in borrow pits where drainage is practicable, earth not leveled off on tops of cuts, scattered ballast, stumps on the right of way, sign and other posts not erect or in good condition, imperfect road crossings.

In rating divisions or sections as to expense it is customary to deduct from the total expense for the year the cost for new construction and all other extra work. The sections are also credited with the number of ties renewed, the amount of ditching done, and the amount of new rail laid, a certain rate being allowed for each unit of such work performed. Where there are different kinds of ballast, such, for instance, as stone and gravel, a higher credit is allowed for the ties renewed in the stone ballast. After deducting these credits the division or section showing the least balance is awarded the highest standing in the matter of expense, and the other sections accordingly. On roads where the rails on the different sections are of different ages or of different weights per yard it is sometimes customary to give some credit to the sections laid with old rails or with rails badly worn, marking them one or more points higher, arbitrarily, after the ratings for joints and surface have been made. The principle of such practice is proper, because it may rightfully be assumed that old rails are splice worn at the joints, as well as that the splices are worn, which conditions increase the difficulty of maintaining the joints in surface. Rails which have been in service less than one year are in such cases considered as new rails. For obvious reasons credit should be given the sections laid with the lighter rails.

On various roads the ratings are marked by the roadmasters, supervisors, the assistants of these officers, assistant engineers, division engineers, and in some cases by the division superintendents, no officer who is eligible to a prize or for special mention marking for his own division. On sound principles, however, no officer who is liable to benefit by the results should be permitted to mark at all, for one disposed to be unfair could put relatively low marks on some of the best divisions, which would certainly inure to his own advantage in the general average. On the Boston & Albany R. R. the chief engineer and the division roadmasters compose the marking committee. On a fewer number of roads, however, it has been the practice to compose the marking committees of section foremen, each foreman marking every section except his own. The idea in this arrangement is to educate the foremen in critical methods, the supposition being that such a training ought to make them better judges of their own work, and at all events develop their faculties for observation. On some roads where the prize system is in force all of the section foremen are taken over the road together, after the prizes have been awarded, so as to give them the opportunity to see for themselves the appearance of the prize section and compare their own sections with others.

On the Union Pacific R. R. the official inspections of track are made by the officers and section foremen together. The section foremen are supposed to critically examine the track and are required to vote their opinions on the section in best condition. There has been no prize system on this road, but inspection trips of this kind are made over each division twice each year, during the spring and fall. The car used on these occasions is illustrated in Fig 529. The platform of the car is mounted on easy riding trucks and the seats extend crosswise the car in tiers, amphitheater fashion, giving those in the rear an unobstructed view over the heads of persons sitting in front. The car has a canopy roof stretched over the tops of well-braced iron posts and side stakes. The seats do not extend entirely across the car. On the side opposite that which shows in the view there is an aisle or passageway the length of the car. At the front of the car there is a cowcatcher and platform, with a swinging door leading from the platform to

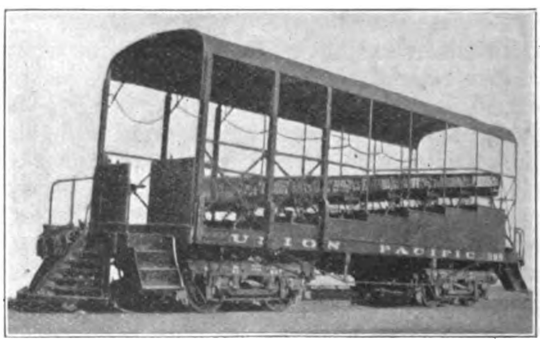


Fig. 529.—Track Inspection Car, Union Pacific R. R.

the first row of seats. At the front of the car, at the right side, there is a seat for the conductor, with an air-brake valve, an air whistle and an air signal for communicating with the engineer. When the car is in inspection service it is pushed ahead of a locomotive, where the best opportunity is afforded for viewing the roadbed and surroundings, and all discomfort and inconvenience arising from smoke and cinders is avoided.

On the Pennsylvania, the Boston & Albany and the Cincinnati, New Orleans & Texas Pacific roads a track indicator car forms part of the train on annual inspections. On the two roads first named the records of this car are not taken into account in determining the standing of the divisions and sections for the awarding of prizes. On the Cincinnati, New Orleans & Texas Pacific Ry. (Queen & Crescent Route) two sets of premiums are awarded, one of which consists of a gold medal, for the best roadmaster's division; and money for the best supervisor's division, best, second best, and third best sections, and best yard on the road. These prizes are awarded according to the usual system of markings based upon observation. The other set consists of money prizes awarded upon the line and surface records of the indicator car, to the foremen in charge of the best, second best and third best sections on the road and to the supervisor whose track has undergone the greatest improvement during the year. In looking over all the awards for one of the years it is interesting to note that in no case did any award as determined by the records of the indicator car correspond with any one of the awards made upon the basis of markings from observation; which is as much as to say that if the registrations of the indicator car were reliable, then none of the divisions or sections awarded premiums upon the usual basis of visual observations were found to be best in line and surface. On this road cards containing the averages of the inspection markings on each section are issued by the superintendents to the foremen, so that they may know in what respect their sections are not up to standard, and try by another year to make improvement in those particulars in which the inspection shows their work to be deficient.

In striving to arrive at the fairest estimate of the condition of a piece of track the relative value or weight of the different subjects marked upon is of great importance. On this matter an experienced trackman would be impressed that the officials who have arranged the details of the markings in the track inspection of many roads about the country have a poor appreciation of the relative value of the various conditions of excellence in track, for in many instances each of the whole list of subjects on which markings are made is given the same importance as line and surface, which, as every maintenance of way man ought to know, is the highest criterion of good track. By all odds line and surface should be given a high count in averaging the markings of the various subjects, because the condition of the track respecting line and surface is the condition which has most, if not all, to do with the riding of cars and the wear and tear to rolling stock. Moreover, to have good line and surface it is essential to have the ties properly spaced (which, by the way, does not imply an even spacing, if the ties be of different sizes in width of face), the bolts tight on the splices and good drainage. As a general proposition it may without serious error be assumed that the foreman who maintains his track in good line and surface attends to numerous other details, such as proper spiking, drainage, tie spacing, tightening bolts, leveling, etc., which frequently receive the same consideration in an average of markings as does the very result toward which the work involved in these items is devoted. It does not follow, however, that good surface will always be found where the ties are properly spaced and aligned, spikes properly driven, bolts tightened, and the drainage conditions good—indeed such conditions might be perfect and still the track surface very poor. Under ordinary conditions the work of maintaining track in good surface is the most laborious matter with which trackmen have to contend, and its cost is the most expensive part of track work. Laying aside the question of safety, line and surface are the most important conditions affecting track. The labor and expense of maintaining track in alignment are, however, comparatively small, so that, as between the two, track surface should receive the greater consideration. In my way of thinking, no basis for determining the standing of trackmen as to the condition of the track under their charge can be rational which does not count line and surface on a scale at least as high as 50 per cent. On the basis of 100 marks for the whole list of subjects considered my idea of an equitable arrangement would find expression about as follows: Surface, 40; line, 10; drainage and banks 12; switches, frogs and side-tracks, 12; expense 20; dividing the remaining 6 marks between policing and such other matters as one might think should be included, in any particular case.

This principle is recognized in the system of marking in force on the Southern Pacific road, where perfection in alignment, surface, and drainage each receive 12 marks; switches and frogs, 10; houses and grounds, 10; spiking, 7; alignment and spacing of ties, 7; ballast, 7; sidings, 5; material, 5; grass and weeds, 5; road-crossings, 3; fence, 3; and policing, 2. On the

Louisville & Nashville R. R. also this matter seems to have been studied more closely than is usually the case, for line and surface (considered together) have the relative value of 25 per cent; ditches and banks (considered together), 25 per cent; policing, 10 per cent; spiking, 10 per cent; switches and sidings (considered together), 10 per cent; joints, 10 per cent; spacing of ties, 8 per cent; and station grounds, 2 per cent. In marking, a half point is allowed, such as 9½ for a nearly perfect condition, on 10 as a basis. On some roads only full points are used in marking for track inspection. On the Illinois Central R. R. the following ratios of relative importance are assumed in computing averages of markings for track inspection: Line and surface, 25; joints and spacing of ties, 15; drainage, ditches and banks, 20; station grounds and policing, 15; spiking, 10; switches and sidings, 15.

The force of the application of this principle of marking is illustrated in a rating of sections published by one of the roads best known for its system of yearly inspections and premiums to track foremen and supervisors. Among the sections of one of the divisions that which took the first prize was poorest in line, poorest in surface, not the highest in switches, not the highest in drainage, not the highest in "general condition," one of the two highest in the rating for expense and the highest in the marking for sidings, the difference between this section and the next best in the last respect being so large as to make the average rating of this section foot up the highest. In line and surface this section was, compared with all the others, remarkably poor, and had these subjects received their proper relative value, or such value as is given to them by the Southern Pacific, Louisville & Nashville and some other roads, the section which received first prize would, by actual computation, have stood next the lowest on the list. This goes to show that in the awarding of prizes to trackmen the system of marking on at least some of the roads of the country are necessarily based upon an erroneous recognition of the relative importance of the conditions which have to do with the excellence of track. The example just cited illustrates how a foreman, by paying special attention to side-tracks, which require the least expense for repairs, and which cut the smallest figure in wear and tear to trains, may take the prize, even though he may neglect those conditions which are by all odds the most important. Under some systems of marking, a section of track in excellent line and surface, but with a spear of grass or a weed here and there on the roadbed, and perhaps a little ballast not trimmed up on the shoulder, would be rated considerably lower than some other section with no better riding qualities but with the weeds all cut and the ballast trimmed to an exact distance from the rail; and still, the material difference of the conditions might be no greater correspondingly than exists in the same man before and after having his shoes polished.

Track Inspection Apparatus.—Mechanical appliances for indicating the condition of track depend for their operation either upon the relative movements of car wheels or upon the throw of the car body. The most primitive device for testing line and surface is an ordinary water glass filled about three quarters full and set upon a window sill over one of the trucks of a passenger coach. If, in running at good speed, no water is spilled the track is considered to be in good condition in the respects noted. This was a test frequently referred to in the "old days," but obviously the record made by an instrument of this class is not of a permanent character, and rough places in the track are neither closely located nor readily traceable. Another indicating contrivance that is sometimes improvised is a level board rested crosswise a hand car and run over the track to indicate places where the rails are out of level. At any considerable speed the jar of the car separates the bubble and the scheme does not work very satisfactorily.

The best known apparatus for track inspection is arranged in a combined dynagraph and track indicator car devised and built by Mr. P. H. Dudley, inspecting engineer with the New York Central & Hudson River R. R. This car has been in service since the year 1881, with more or less regularity on the Boston & Albany and the New York Central & Hudson River roads, but occasionally on other roads. It is 58 ft. long, weighs 72,000 lbs., and in its exterior appearance resembles an ordinary day coach. The interior is conveniently fitted up for the special service to which it is devoted, about half of the car being occupied by apparatus and the necessary facilities attendant upon the taking of records, and the other half partitioned off into living rooms. Under one end of this car there is a 6-wheel truck with a wheel base of 11 ft., and the springs and side bars are so arranged that the load (39,000 lbs.) is evenly distributed among the six wheels. This weight has not been changed since the first records were taken, in 1881, which enables a comparison of results under the same conditions of weight for all the variations in track construction since that year.

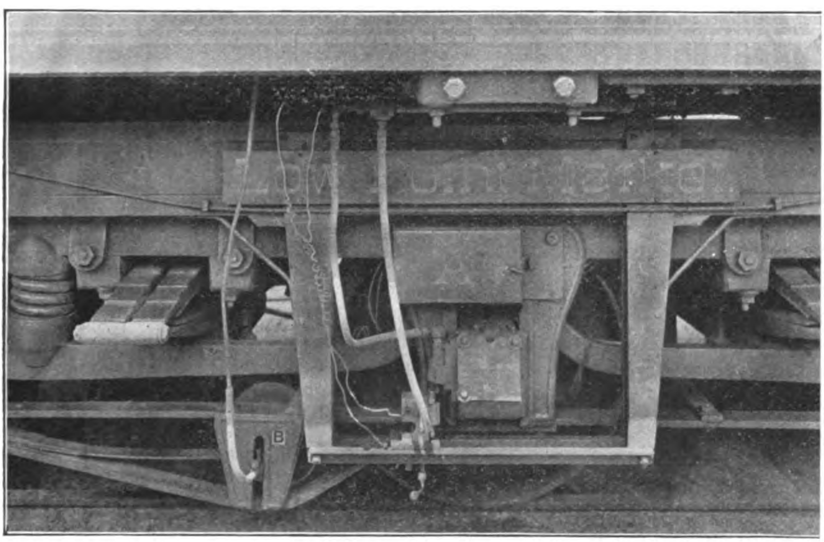


Fig. 530.—Part of Truck, Dudley Track Indicator Car.

The principle upon which the car, with its appliances, indicates the condition of the track is that automatic records are taken of the movement of the middle wheels of this truck relatively to the other two pairs of wheels. Although the middle wheels sustain their share of the load, their connection with the truck frame and with the other wheels is such as to permit freedom of movement vertically, so that the middle wheel on either side moves in response to the irregularities in the rail quite independently of the other two wheels on that side. The wheels on the middle axle are 33 ins. in diameter, with cylindrical treads (not coned), and they are mounted on the axle to run snugly on standard-gage track—that is, with less side play for the flanges than is permitted by the M. C. B. standards. Considering one side of the track, for convenience, it is readily seen how that the movement of the middle wheel relatively to the other two must indicate the amount of surface undulation in the rail and irregularity of alignment within any stretch of 11 ft. of track; in other words, all abrupt irregularities in line and surface are detected. Sags or other irregularities extending over a considerable stretch of track (comparatively with the wheel base of 11 ft.) are not discovered. The middle axle is connected by worm gear with the recording apparatus in the car, which is placed directly over the truck. The journal box movement of each of the middle wheels is transmitted to small levers or recording pens in the car above, which reproduce the movements of the wheel upon a roll of paper drawn over an iron table with a convex top. This roll of paper is 20 ins. wide and is moved at a rate proportional to the speed of the train—one inch of paper to 50 ft. of track. The markings for the irregularities in the rail (vertical scale), however, are to full scale. The gage of the track is detected by a pair of small disks running between the rails, each being pressed against the side of the rail head by springs, which compel the disk to follow the inequalities in the gage and cause the transmission of a record of the same to the paper diagram in the car above. The disks are carried on an auxiliary axle journaled in the pedestal marked "B," Fig. 530. This axle rises when either of the disks strikes the point of a facing frog, and to throw them into gage again requires the attention of an operator. As seen in the figure, the axle is in the raised position and each disk stands over the rail head instead of between the rails, as in the service position.

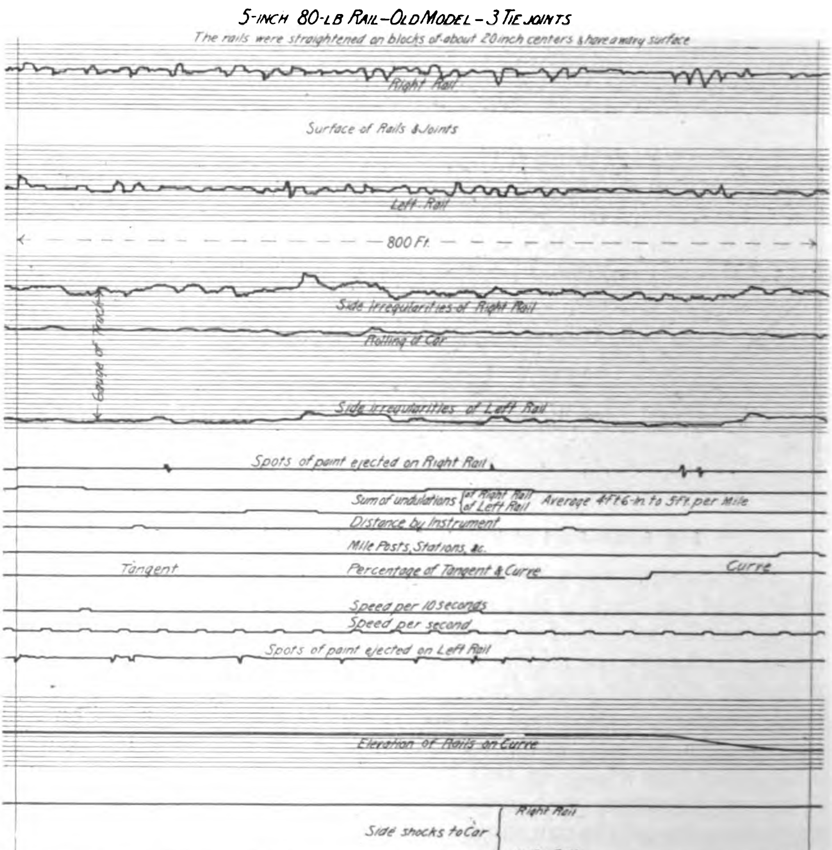


Fig. 531.—Complete Record of Track Inspection by Dudley Indicator Car, New York Central & Hudson River R. R.

The recording pens are 17 in number, showing the surface irregularities and alignment of each rail, the gage of the rails, the rocking or rolling of the car, the spotting of each rail; the summation of the undulations in each rail, in feet and inches per mile, recorded in amounts of 6 ins.; the distance traveled by the car, the same being indicated every twelfth of a mile or 440 ft.; the location of mile posts, stations, bridges, etc.; the percentage of tangent and curve, the speed of the car during each 10 seconds, the speed at the end of each second, the elevation of the outer rail on curves; and the side shocks to the car body, in distinction from side shocks to the truck in following the rails. Figure 531 is a reproduction, to reduced scale, from a complete record showing the markings of all the pens during an inspection of a stretch of 800 ft. of track on the New York Central & Hudson River R. R.

The record made on the paper by each pen is a continuous line traced in red ink. There is a chronometer pen which marks on the paper every second, and as the movement of the paper is proportional to the distance traveled, this time register serves as a means of determining the speed of the train at any instant. The pen which marks the location of stations, bridges, etc., is operated by an observer, who presses a key when the car passes any point the location of which is desired on the diagram. By setting the mechanism when a mile post is found, this pen can be made to record mile posts automatically, and in addition to this a bell is made to ring in advance of each mile post. The change from tangent to curve, or vice versa, is indicated by an offset in the line traced to show that feature. The relative length of the offsets determines the percentage of tangent and curve. For each red line giving information regarding some feature in the condition of the track a number of straight blue lines are marked one tenth of an inch apart, which serve as reference lines for the curved or irregular red line denoting the record. By an exceedingly ingenious arrangement the dropping and rising of each end of the middle axle is made to work a ratchet which sums up the amount of the undulations in the rail, however small—that is, whether of sufficient magnitude to be registered or not. As soon as the undulations amount to 6 ins. one of the pens on the recording table makes a mark on the diagram, so that it is possible to get the summation of the undulations in a given distance, as one mile, for instance. The apparatus for indicating the elevation of curves consists of a pair of pipe-connected cylinders, one on each side of the truck, each cylinder being partly filled with water and carrying a float.

Of course the exact location of any irregularity in the condition of the track is determinable by the relative position of the record mark on the paper, but a more convenient arrangement for the information of the trackmen concerning the track surface is provided. Hanging against each side of the truck, on a light frame supported by the end wheels, independently of the frame which carries the weight of the car, there is a device for marking the location of rough track surface, known as the "low point marker" or "spotter," The mechanism consists of a small force pump or pneumatic squirter in connection with a tank of blue paint in the car above. This apparatus is supplied with pressure by a branch from the air brake system, and it is fitted with an adjustable valve so arranged that it may be set to open upon the depression of the middle pair of wheels in excess of any desired amount. The precision with which the undulations are measured is so fine and the adjustment of this valve so sensitive that the valve will open or remain closed if the depression is but one thousandth of an inch greater or less, as the case may be, than that for which the mechanism is set. Upon the opening of the valve a quantity of the paint is splashed against the web of the rail, opposite the point of depression, thus indicating where rough places in the track surface are to be found. As previously stated, a pen on the recording table, for each rail, makes a mark on the diagram every time paint is ejected. Formerly the spotting apparatus, as used on the Boston & Albany R. R., was set to discharge at a depression of $^5/_{16}$ in., but as heavier and stiffer rails came into use the surface conditions of the track were so largely improved that the apparatus was set to discharge at a deflection of $\frac{1}{8}$ in.

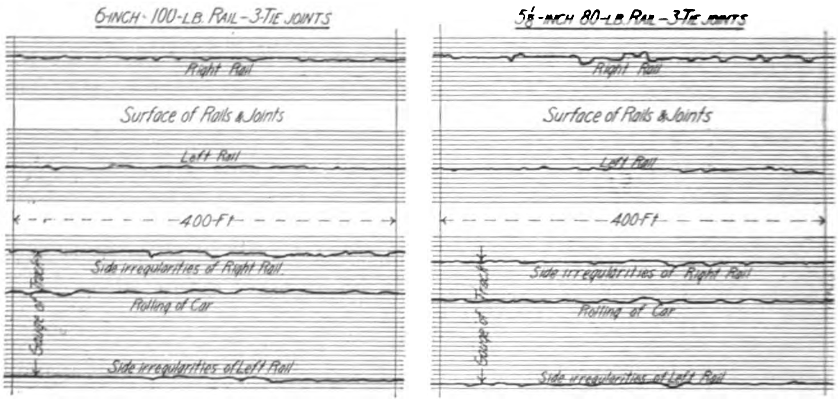


Fig. 532.—Partial Records of Track Inspection by Dudley Indicator Car, New York Central & Hudson River R. R.

The left-hand diagram in Fig. 532 is a record of the surface undulations and irregularities of alignment in a stretch of track on the New York Central & Hudson River R. R., laid with 6-in., 100-lb. rails. This may be taken as a sample of track in good surface, the extreme undulation in either rail being within one tenth of an inch. The alignment of the rails, as shown by the diagram, is not quite as smooth as the surface. The right-hand diagram in the same figure shows the irregularities of surface and alignment in 80-lb. rails $5\frac{5}{8}$ ins. high, on the same road. Numerous features of track condition, apparent upon inspection and comparison of the diagrams in these three illustrations, are left to the study of the reader. It should be understood that the record for "surface of rails and joints" makes the track appear rougher than it really is, because when the head wheel of the truck drops into a low joint, for illustration, the middle or registering wheel is high, relatively to the other two wheels. Again, after the middle wheel has passed the low joint the dropping of the rear wheel into the sudden depression causes the middle wheel to again register high. Thus, where a low joint or other spot occurs abruptly in a stretch of track the surface of which is otherwise smooth, with no point higher than the general surface, the record on the diagram shows both high and low. In studying the diagrams this fact should be borne in mind.

On the New York Central and the Boston & Albany roads the results of an inspection of the track with this car, as shown by the continuous record sheet, are plotted on a condensed diagram of the whole road, an example of which, portraying the condition of 40 miles of double track, on the New York Central road, is shown as Fig. 533. On this diagram the space between each two vertical lines represents one mile of track, and each space between horizontal lines represents the one-hundredth part of an inch. The heavy, plain, wavy line indicates the condition of the track surface as ascertained by one of the annual inspections, and the broken line the condition of the track at the inspection made four years previously.

The average condition of the track for each mile is indicated at the middle of the space for that mile by the hight of the line above the base line, which shows, in hundredths of an inch, the average amount of undulation per rail length. It should be explained that in plotting these lines the summation of the undulations in the rails for a mile, as indicated by the recording apparatus on the car, is divided by 176, the number of 30-ft. rails in a mile. Thus the results for each mile are relative to the base line and may be compared with each other. The line marked "Age of Steel" gives the length of service of the rails, each horizontal line representing one year. Thus, the diagram shows that, at the time the inspection was made, the rails in the west-bound track at Mile 318 had been in service four years, and those in the east-bound track, at the same point, two years. The line marked "Percentage of Tangent and Curve" shows the approximate alignment of both tracks, per mile, the percentage of tangent being marked on the left side, and that for curvature on the right side of the space for the mile, each space between horizontal lines representing 10 per cent. Thus, for instance, in the 311th mile it will be noticed that there is only one mark, which extends across all the 10 lines, at the left, indicating that the entire length of track for that mile is tangent. It will be noticed that in the 310th mile the mark at the right extends over four lines, and the mark at the left over six lines, indicating that 40 per cent of the track is on curve and 60 per cent on tangent. The line marked "Profile" shows the gradients of the road which, of course, are common to both tracks. For the profile scale each space between horizontal lines represents 10 ft. of elevation. As the gage of the track was found to be "perfect" the line showing this condition was, of course, straight, and therefore eliminated from the diagram, as was also the line showing "side irregularities of the rails," the track being in "perfect" alignment.

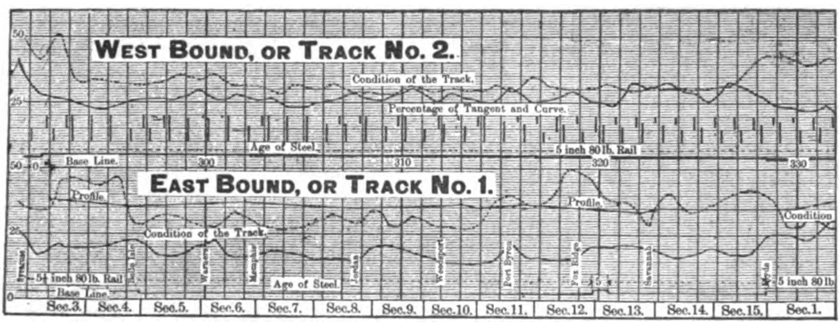


Fig. 533.—Condensed Diagram of Track Inspection (40 Miles), New York Central & Hudson River R. R.

Such diagrams are of value chiefly to compare the condition of the track one year with another. The roughness of the rail from unequal wear, producing a wavy surface, is readily shown, and also the weakening at the joints due to the wearing of the splice bars. A comparison of the surface indications in Fig. 531 with those in the right-hand diagram in Fig. 532 shows the effect of improper straightening of the rails, as explained under the head line (Fig. 531), both rails being of the same weight. As to the relative surface conditions of rails of different section, the sum of the undulations of the 100-lb. rails, of which record is made in Fig. 532, averaged 1 ft. 9 ins. to 2 ft. per mile. The average for the 80-lb. rails, the record of which is shown in the same figure, was 2 ft. 6 ins. to 3 ft. per mile. The average for 4½-in. 65-lb. rails was about twice that for the 80-lb. rails. As the track in every case had been maintained in first-class condition, the relative summations of the undulations for the rails of the various sections is some measure of the influence of stiff rails on track surface. Information deduced from the study of these diagrams from year to year has been an important consideration in deciding upon the increase in weight of rail by the New York Central road; particularly in the year 1883, when Mr. Dudley designed for that road an 80-lb. rail 5 ins. high. This rail was put in service the next year, at which time it was the heaviest rail in use on any road in this country.

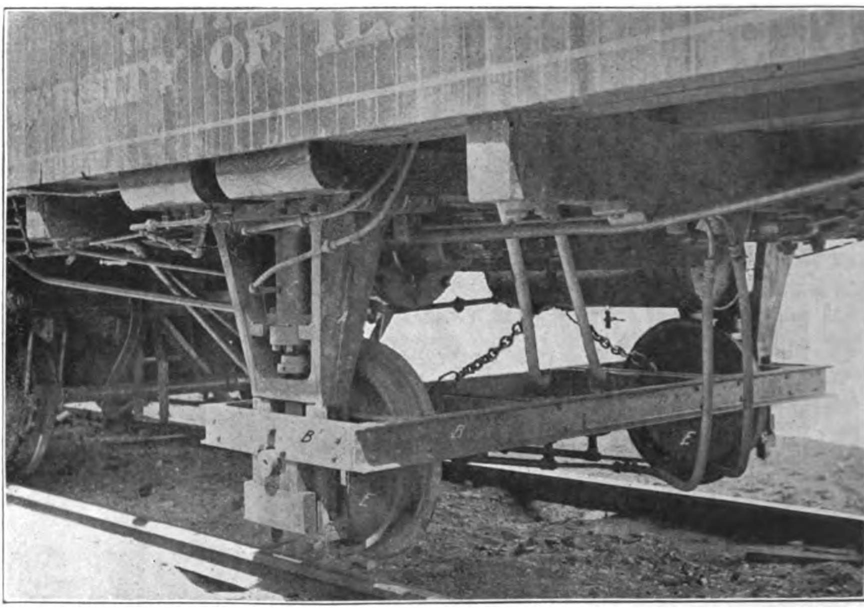


Fig. 534.—Track Indicator Car No. 609, C., C., C. & St. L. Ry.

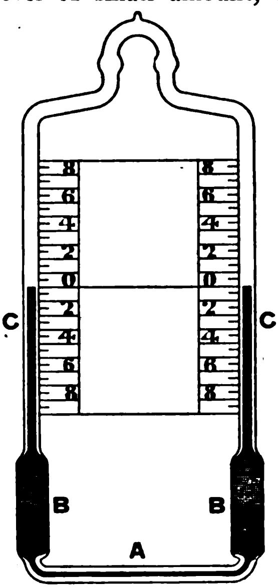
Another track indicating equipment of equally elaborate construction, but designed on a different principle, is contained in Dynamometer Car No. 609 of the Cleveland, Cincinnati, Chicago & St. Louis Ry., owned jointly with the railway engineering department of the University of Illinois. This car was equipped for dynamometer tests of engine capacity, train resistance, tonnage ratings, locomotive road tests, air brake tests and, in addition, for automatic inspection of track. The car is 35 ft. long, patterned after the style of a freight caboose, and is carried on two four-wheel passenger trucks. The car weighs 33,000 lbs. The apparatus for track inspection is entirely separate from that used in taking train resistance. It was designed to record autographically the following conditions: (1) irregularities in track surface; (2) variations in track gage; (3) superelevation of the outer rail of curves; (4) time intervals. The recording part of the mechanism consists of charts or long sheets of paper drawn over rollers, with pen markers controlled by the motion of the receiving apparatus under the car. The rollers or cylinders over which this chart is drawn are geared with the car axle, producing motion in the chart proportional to the speed of the train. Referring to Fig. 534, the receiving part of the apparatus, or that which is acted upon direct by the irregularities of the rails, consists of two wheels of 20 ins. diameter, one for each rail, attached to separate axles which are journaled to a rectangular frame (B), built of channel irons and supported upon cast hangers (A) rigidly attached to the car midway between the trucks. The wheel bearings and the frame (B) are free to move vertically in the guides of the hangers. The axle of each wheel is short, extending to inner bearings attached to cross pieces of the frame B and terminating in collars which limit the outer motion of the wheels. These wheels, by their weight and by spring pressure acting outwardly against them, are constrained to follow the rail in all its irregularities in surface, gage and alignment.

These wheels, through their axles and bearings, are in communication with cylinders, the pistons of which follow all the movements of the wheels due to changes in alignment or surface. These cylinders, known as "receiving" cylinders, are connected by means of $\frac{3}{4}$-in pipes filled with oil with small recording cylinders located on a table in the car above. The piston rods of these recording cylinders carry marking pens which trace records of the motion of the wheels upon the moving chart, as above explained. The piston which receives motion from each wheel due to vertical undulations in the rail surface is in a vertical cylinder (C) which stands directly over the wheel bearing. The piston rod is attached to the top of the journal box, so that any vertical motion of the axle sets the apparatus at work. The piston which receives motion from the wheels due to variations of gage is in a cylinder interposed between the ends of the short axles of the two wheels. One end of this cylinder abuts against the axle of one of the wheels, and the end of the piston rod abuts against the end of the other axle. The end of this piston rod is provided with a collar, between which and the stuffing box is a heavy helical spring, the pressure of which serves to hold the flanges of the wheels against the rails. It is evident, therefore, that any relative horizontal movement of the wheels causes movement of the piston rod, which acts upon the fluid in the cylinder and in this way transmits motion to the recording cylinder above. On the axles there are collars to prevent the two parts being forced apart far enough to take the wrong side of frog points when passed in the facing direction. The record of the elevation of one rail above the other is obtained by attaching a marking pen to a cord passed over pulleys and attached to two lignum-vitae floats in iron mercury cups placed on opposite sides of the car and pipe-connected underneath. When the apparatus is not in use the receiving wheels and axles and the bearing frame (B) are raised from the track by an air lift and locked in position, as shown in the illustration. The wheels can be quickly lifted out of action at any time. When the car is to be used for track inspection it is raised and blocks are inserted in all the springs, giving the car body rigid support and preventing motion relatively to the wheels. To obtain good results the car is run at a speed of 10 to 15 miles per hour. The record paper is 24 ins. wide and the rate of travel is 26.4 ins. per mile. The paper is in rolls of sufficient length for inspecting 400 miles of track and it may be made to feed ahead whichever way the car is moving. The recording apparatus includes several pens electrically operated, for recording from the observation tower of the car.

The Chicago Great Western Ry. has used a track indicator devised by Mr. Chas. A. Stickney, assistant to the president of that road, which was put into regular service in 1896. This indicator is arranged to show sharp defects in the surface and alignment of the track; is simple in construction and is operated by the lurching of the car body. It consists of three flat spring levers each about 10 ins. long, clamped at one end, and lying horizontally in a direction lengthwise the car or parallel with the track. The free end of each lever terminates in a heavy tip, or hammer head, the inertia of which, when motion is imparted to it by the throw of the car, causes the lever to vibrate. Two of the spring levers (one for each rail) are clamped so as to vibrate horizontally, or in obedience to the side throw of the car body, one responding to a throw toward the left, the other to a throw toward the right. The third lever is clamped in a manner to vibrate vertically, or in response to a jolting of the car up and down. Each lever is put in tension by a bearing screw so adjusted that the lever will not vibrate from the usual motion of the car but will respond to a sudden jolt or lurch. The vibration of the lever causes it to strike against a binding post, the contact so made closing an electric circuit and setting in action the registering apparatus, which consists simply in an electro-magnetically operated needle, which punctures a paper ribbon passed between guides at a speed proportional to that of the train. This ribbon or strip of paper is unwound from one roller and wound up on another, and is moved between a pair of feed rolls belted to the car axle. It is not possible, from the mark registered on the paper (since the vibration of all three levers causes the registration of the same kind of mark), to determine whether the irregularity in the track at any point where a mark is registered is a defect in surface or alignment, or upon which side of the track it is located. The record simply indicates that the track is rough at that point. When starting out upon an inspection trip a reference mark or puncture is made upon the paper, by a push button arrangement, and the same is done when passing mile posts, bridges, stations or other points desired for reference. Irregularities in the track can thus be located closely by scaling off the distance from the reference point marked upon the paper.

This instrument is placed in a box or chest about 24x24 ins. x2 ft. high, which is set permanently upon the floor of one of the regular coaches of the road, over a truck. When not in service the lid of this chest is kept locked. This car makes its runs on the regular trains of the road, and at regular intervals an attendant is placed in charge of the indicator, the intention being to make an inspection of the whole road twice each month. During the remainder of the time this attendant is employed at plotting the results of his inspection trips. Each indication of the instrument for each trip is plotted upon a diagram, the results of a number of trips being recorded upon the same diagram, the intention being to compare the condition of the track as registered on the various trips. It is also the business of this attendant to notify the section foremen as to the location of defective points in the track, and if upon successive trips an indication appears repeatedly at the same point, the matter is brought to the attention of higher authority and an investigation is made to ascertain the reason why the defect has not been corrected, or what the difficulty may be at the particular point, in case the section foreman has made effort to repair the track.

On the Chicago, Milwaukee & St. Paul Ry. use has been made of an instrument for inspecting the elevation of curves. This is known as the "equilibristat" and was contrived by Mr. D. J. Whittemore, chief engineer of the road. Briefly stated, the purpose of the instrument is to determine whether the car floor remains parallel to the plane of the rails, or in a state of equilibrium, while rounding a curve, and, if not, to measure the amount of deviation from the position of equilibrium. The instrument is essentially a U-shaped liquid level, the readings of which are magnified by causing the upper portion of the liquid, in the two branches of the "U," to pass into capillary tubes. The instrument consists of a continuous glass tube in the shape of a rectangle about 4 ins. wide and 10 ins. high. The tube is sealed and unobstructed throughout the entire circuit of the rectangle and has three different calibers as follows: Across the bottom of the rectangle the section (*A*, Fig.535) is quite small, comparatively, and is known as the "retarding" portion; just above the lower side of the rectangle the section (*B*) on each side is expanded to bulbous proportions for about 2 ins. in length and is called the "containing" portion; above this the sides and top of the rectangle are contracted to a section of $^3/_{32}$-in. caliber, or to a size something like that of an ordinary alcohol thermometer; this latter portion of the tube (*C*) on each side, is known as the "indicating" tube. The relative calibers of the retarding, indicating and accumulating sections, respectively, are as 1, $2\frac{1}{4}$ and 10. The lower portion of the rectangle, up to the middle of the containing tubes, is filled with mercury, and above this the indicating tubes are filled with colored alcohol. The mercury is free to flow from one containing tube to the other, through the retarding tube, the purpose of restricting the diameter of the latter being to make the instrument insensitive to rapid changes of level of small amount, or shocks caused by small inequalities in the



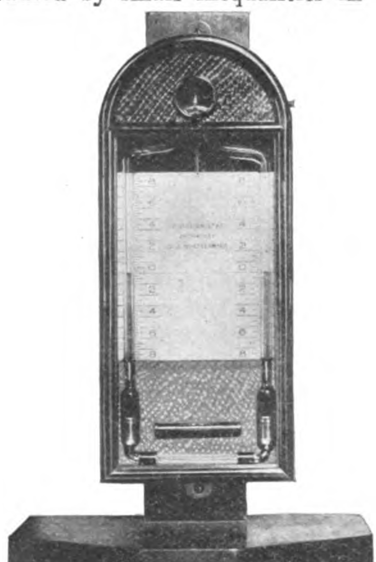


Fig. 535.—Whittemore Equilibristat—Fig. 536.

track surface. A scale plate is hung within the rectangle, with zero marks at the top of the alcohol columns in the indicating tubes. This scale plate is adjustable by a screw, to compensate for change of temperature. For an obvious purpose a level bubble is attached to the instrument. The whole is placed upright within a glass-covered case (Fig. 536), the instrument complete occupying about the same space as an ordinary cigar box.

The instrument operates on the principle that if placed on the floor of a car, with the rectangular tube transverse to the axis of the car, the inequality of the liquid in the two indicating tubes will show the inclination of the car floor. Thus on track level across, the liquid in the indicating tubes ought to stand at zero; that is, at equal hights in both tubes. On a curve, however, with the car standing still, the reading of the liquid column in either of the indicating tubes will give the elevation of the outer rail of the curve in inches, the unit of the scale division and the calculation of the instrumental dimensions being arranged to this intent. When the car is in motion, however, the centrifugal force acting upon the mercury in the tube tends to raise the fluid in that side of the rectangle which is toward the outer side of the curve; and if the curve is properly elevated for the speed at which the car is moving, so that the car floor remains parallel to the plane of the rail surfaces, the liquid within the indicating tubes will stand opposite the zero of the scale. An improper elevation of the curve for the speed at which the car is moving is indicated by the reading of the liquid columns, on the scale, as so many inches excess or deficiency, as the case may be. Thus, to use the instrument it is only necessary to place it on the floor of the car (adjusting it so that it rests level transversely of the car when the same is standing on track level transversely, if such may be necessary, owing to an unequal loading of the two sides of the car or by the unequal action of the car springs) and to run the car at the speed for which the elevation is desired. If the elevation in the rails is suited for the speed the instrument will read zero, but if not, the reading of the instrument will indicate the number of inches in the way of correction which must be made to properly elevate the curve. The instrument was intended for the use of roadmasters and to be placed at convenient points in business cars.

Perhaps a word should be said regarding the practical benefits of track-indicating instruments. While the foregoing account shows that such instruments undoubtedly give reliable indications of the condition of the track, it is rather too much to say that the use of such devices is essential to a high standard of excellence in track. It is proper to state that, so far as practical results are concerned, an expert trackman is equal to any task of track inspection. If such was not the case one would be led to inquire how track could be put into smooth condition to start with. All that any indicator can do is to point out the need of repairs, but the final test of line and surface is always the "eagle eye" of the section foreman. As a means of keeping tab on the work of the section foremen, these instruments may be of some value. In this connection, however, it seems that the Stickney instrument, on the Chicago Great Western Ry., is the only one which has been put to regular use. For use on official inspections such devices undoubtedly have their value. Thus, for instance, the Dudley car has been used for many years on the Boston & Albany and the New York Central & Hudson River roads to ascertain the progress which has been made on those roads in reducing the amount of surface irregularities in the rails, one of the chief factors of which has been a more or less gradual increase in the weight of rails, on considerations already stated. While it was known that an increase in weight would produce a stiffer rail, the records obtained by this car have shown just what the relative decrease in the surface irregularities has been as heavier rails have been laid from time to time. In all cases where there is inaugurated a definite policy to progress toward some standard of excellence in track surface and alignment it would certainly seem worth while to make use of scientific apparatus of this kind. One trip over a road or division tells the story, and no part of the track escapes attention. An inspection of the track on foot, by visual observation, taking note of all the details disclosed by such apparatus would never be attempted. The most convenient method of inspection for the trackman, and one that is sufficiently accurate for every practical purpose coming within his supervision, is to ride over the track on the engine of a fast train, following up the trip by a careful inspection on foot of the rough places noted from the engine.

There are other track-indicating devices that have been in service. The Pennsylvania R. R. has a track indicating car less elaborate than the Dudley car, and the Pennsylvania Lines West have another. Portable instruments devised on the principle of the pendulum, for service in passenger coaches, have been used on some roads. Paint squirters, to mark the track at rough places, have in some cases been attached to ordinary business cars to be operated by hand control. The chief engineer's car on the Michigan Central R. R. is so equipped.

The Premium System.—The premium system is understood to mean the practice of awarding prizes to division roadmasters or supervisors and to section foremen whose track is found in the best condition, as announced by the results of the official inspections. Quite frequently also there are prizes for division officers and foremen standing second best, third best, etc. Such prizes usually consist of gold medals; money, in amounts from $25 to $100, and sometimes more; gold watches, gold-headed canes and perhaps other desirable things. On the merits of the premium system the opinions of experienced maintenance of way officials and employees differ. Some engineers who claim to have watched closely the results of the annual inspections and the awarding of prizes think they are a grand success, while others who profess a similar experience declare that, as conducted on some roads, at least, they are nothing better than a "grand farce." On the part of those who favor the system it is claimed that enthusiasm in the work is aroused among the persons eligible to the prizes; that these men, as well as the employees working under them, appreciate the recognition of the company for the ability and faithfulness displayed; that the pride of all the men in the work is stirred; and withal that the results of the system certainly show in better and safer track at a reduction of maintenance expenses. Mr. Geo. R. Brown, formerly general superintendent of the Fall Brook Ry., has stated that the adoption of the premium system for section foremen on that road (three premiums of $40, $20 and $10 on each division), resulted in an improvement of at least 25 per cent in the condition of the track, with annual pay rolls $37,000 to $42,000 less than the average for eight years before premiums were given. The road was 257 miles long, all single track, the tonnage averaged about 6,000,000 yearly, and there were no conditions of maintenance essentially different under the two systems, except that an average of 4½ miles of new side-track was built each year for ten years under the new system, and the expense of maintaining this was included in the comparison. Another idea which has weight with some managements is that yearly inspections and the awarding of prizes surround the work with an aspect of form, and instill into the minds of the men proper respect therefor. On the other hand, it is contended that the practice of giving prizes for excellence in the performance of duty is not promotive of a high order of discipline, and in the reasons offered there are evinced various shades of opinion.

In the first place, it is claimed that some compromise with good reasoning is essential to the assumption that all section foremen or division track officials can compete on the same footing. Like effort, even if judiciously directed, will not always produce results which are visibly alike; and it seems to be quite generally admitted that the task of determining which is the best piece of track, where differences are slight, is a difficult matter. A great many people believe that close contests cannot be decided with a certainty of fairness where the decision is dependent in large degree upon human judgment or where the results of the contest cannot be positively determined. Where men contest as in a foot race or in shoveling dirt the conditions may be made equal and the results of accomplishment show indisputably on the face of things; but where a contest must be decided by striking an average of opinions the determination is not positive. The reward, however, is something positive and substantial. As an illustration of the difficulty of deciding upon the relative condition of two pieces of track one might consider what fine points of judgment would need to be exercised to tell to a certainty the difference between two pieces of track often found alongside of each other, as in comparing the two tracks of a stretch of double-track road. How much more difficult then would it be to decide fairly between two sections of track in nearly the same condition, but where some hours have intervened between the time when each was seen. On these questions some quotations from a discussion before the Eastern Maintenance of Way Assn.. in 1901, by Mr. F. C. Stowell, its secretary, and roadmaster with the Boston & Maine R. R., are much in point. He said, in part:

"Much mystery has always obtained in my mind as to the possibility of arriving at a just distribution of awards by the method of inspection and basis of award commonly prevailing. It is inconceivable that any number of men, however fair minded, capable or discerning, can, as the result of a more or less flying trip over long stretches of track, pass detailed, comparative judgment on the numerous sections thereof, without liability, yes probability, to frequent and gross error. And this is not a suspicion of, or reflection on, either the efforts, good intentions or ability of the judges. Such observation is bound to be a too superficial basis of judgment, and though it may locate the prize or prizes, it will rightly lack the respect of the competing foremen, and so fail to encourage the 'morale' intended. Next, as to the significance of the conditions inspected. . . . . There are a limited few trunk lines in this country being put by tremendous appropriations of capital in such a state of physical excellence that the conditions of the various sections thereof are approaching such a state of similarity that it is fair, perhaps, to judge of the merits of the foremen by comparison alone of the physical condition of their respective sections. But beyond these isolated examples the great majority of track mileage presents such dissimilar physical conditions that the labor and skill necessary to reach a certain state of refinement on one section may be much more or much less than that required to reach a similar state on a neighboring section. What is it for which a prize is awarded? Is it not for the greatest amount of the most intelligently directed labor put forth per man? And what should be the evidence? Surely not always the best section on the road. It should rather be the best section, in view, briefly, of both the natural and accidental obstacles encountered in putting up the same between periods of inspection. In other words, the reward of merit should go to the man who has wrought the greatest improvement from prevailing conditions. What roadmaster has not, when accompanying his superiors on inspection trips, seen the most trivial circumstances of accident unknowingly turn the scale of opinion temporarily against his best foreman, and then perhaps some more fortunate circumstance (also accident) bring undue comparative praise to a much less worthy man on the very next section? Such, as it appears to me, is the twofold mistake of granting the palm of merit for maximum perfection of track only, and based only on superficial examination. I cannot dispel from my mind that such awards should go for conditions of maximum refinement, only when accompanied by equal evidence of improvement over previous condition. And I admit that this criterion of judgment makes the task of justly awarding prizes among foremen on the average properties most unsatisfactory, if not quite impossible. It necessitates that the judges should have the same detailed, day-to-day familiarity with individual conditions of maintenance of the particular track under inspection as the roadmaster himself, which is hardly practicable."

Again, it is believed by many that the customary awards for such contests are too disproportionate for the close degree of excellence between a high record and the highest; as, for instance, be the average markings of a number of section foremen as close as can be without being equal, one foreman, or at most, two or three, take the substantial recognition (the prizes) while the showings of the other foremen count for naught, at least so far as official recognition is concerned. If it was arranged to conduct a rigid inspection of each section by a party of experts traveling all the way on foot, and then to grant an increase of pay to all foremen whose track was found above some certain standard or marking, the increase to continue as long as that standard was maintained, such a scheme would conform more closely to business principles, because then it would be possible for each and every foreman to secure substantial recognition for results accomplished. By the prize system, as usually conducted, such a possibility is limited to one or two persons only, no matter how high the standing of all the others. In the natural order of things effort is rewarded somewhat in proportion to accomplishment, but in the ordinary prize system the reward for the efforts of all the foremen combined goes to one man. In its practical workings, therefore, the system is, in some of its aspects, like a game of chance. On this point an engineer of much experience, connected with one of the large railway systems of the country, where the prize system has long been in vogue, says: "Regarding the prize system, I have long held to the opinion that it ought to be abolished. As to the fixing of a standard of excellence, that is quite a different matter, and if some substantial recognition was given to them that attained it, some good might result, and there would be at least a great deal less ill feeling." The justice of the foregoing proposition was recognized by the Fall Brook Ry., as shown by the annual report of the general superintendent in 1898, in reference to this matter, as follows: "When the annual inspection was made this year it was found that the condition of the tracks, compared with the cost of maintenance, was so generally good that in awarding premiums to section foremen for the best track it was necessary to again depart from the usual practice of giving first, second and third premiums; and we have divided the total amount of premiums assigned to each division equally among seven of the best sections on each division."

Men of another persuasion consider that the offer of premiums for excellence in work performed is a reflection upon the integrity of the foremen; that where men of strong character are selected and put in charge of work the ordinary wages are a sufficient inducement to attend strictly to duty, which is all that should be expected of any employee. It is therefore the opinion of some persons that when there arises the need of stimulating the foremen to their work by prizes it is time to begin looking for a better class of foremen. The fact that many roads succeed in keeping up good track at economical expense without giving prizes is considered evidence that, under good management, good work can be done independently of the prize system. The competitive feature necessarily partakes of the idea of turning out work on the contract plan, and men who will jump in and exert themselves for artificial rewards are not always the men who have the interests of their employer most at heart. It is also said that, on general principles, the giving of prizes to adult persons is creative of jealousy and is never satisfactory except to the beneficiaries of the system. The love of prizes is "a root of many kinds of evil," the cause of much misery among men and the ruination of many a man. One of the manifestations of vanity is the desire to always place some man or thing the highest of a class.

It is quite commonly understood that in the majority of cases, the premium system works a decided hardship upon the employees or common track hands, and some have denominated it a "man killer." I have heard this view corroborated by fair-minded men in position to know, particularly by an intelligent division track official on one of the roads best known for its premium system to trackmen. It is proper to say that this man had himself, at one time, been the recipient of the highest prize to division track officers. Considering that many section foremen are men of limited education, it is to be expected that a system of awards in which physical exertion is one of the factors essential to the showing of the successful competitor, would lead to a good deal of driving of the men in their work. In this connection, also, the system would seem to be lacking fairness in the respect that the men of the section have no participation in the prize which goes to the section; which makes it appear that the result of their extra effort is monopolized by the foreman. The official distribution of prizes among track laborers is rarely or never heard of. Drawing a mental picture with these facts in the background the system appears like a scheme whereby the foremen are urged to fret and the track hands to sweat, all summer, in order that the foreman may "win the gold watch" in the fall. It is safe to say that in the work and conduct of section foremen there are aims more commendable than that of getting all the work possible out of the men. This fact might be borne in mind wherever it is the practice, in making promotions to the position of supervisor, to consider only those foremen who have been recipients of premiums.

Another objection to the prize system is that, in its practical workings, there is a tendency to spend too much time on finery that should be put on track surface. Some interesting stories are told of efforts to put the gilt edge on things just before the day of inspection. Section men have even gone to the pains to sweep the track with splint brooms, and foremen have been known to get their men out in the night to attend to some ornamental feature that had been overlooked during the days of "preparation." On the other hand men have been known to grow weary of the competition and fail to maintain the intended esprit de corps. It has been stated officially that on one of the large railway systems there was, at one time, a secret understanding among the supervisors and foremen whereby certain of the forces would not compete for the prizes every year, thus conspiring to pass the honors around in turn, without overexerting themselves. On the real merits and workings of the premium system an outsider frequently finds roadmasters or engineers non-committal, out of desire not to contravene the opinions of higher authority. It is no secret that on some roads where prizes are given for excellence in track maintenance the system is more favorably regarded by the general officers than by those of division rank, like roadmasters and division engineers.

It is the opinion of many men who have had experience with the premium system that the inspections should not be made at regular or stated intervals; that to secure the best results the inspections should come at varying periods and without previous warning, or during any season of the year. It is believed that with periodical inspections the tendency is to devote too much energy to a particular end at the appointed time, when the principal aim of railway managements is to maintain the track up to a good standard at all times. From a business standpoint the railway company is not so much interested in what men are able to do by way of special preparation as in what they are in the habit of doing all the year round. A system which approximates to this idea is that of the New York Central & Hudson River R. R. On the main line of this road, between New York and Buffalo, the track is inspected three times a year, and the standing for premiums is based upon an average of the markings of the three inspections. In order to obtain the best results the standing should be based upon the general count of all the features marked. It has been the practice in some cases to give several prizes on each division of a road for excellence in different lines of work; as, for instance, one prize for best surface and alignment, another for joints and spiking, another for switches and frogs, another for ballast dressing and banks, others for ditches, policing, etc. Such a system might induce some foremen to neglect parts of the work in order to make a showing in others.

The practice which many roadmasters have of watching closely the reports from the various sections and discussing the same with the foremen is considered to be wholesome, and many think it exerts a sufficient moral effect to enliven the proper amount of interest. As part of this plan it is well to watch the distribution of the labor among the various kinds of section work, commenting upon the results accomplished and upon comparisons with the showings of other sections, where it is thought that a little urging is necessary. It is also the plan of some roadmasters to prepare at the end of the year a condensed statement of the cost of the different kinds of work on each section, giving the length of track worked, the number of switches, length of side-tracks, etc., and send it to the foremen for their information, without comment. Many roadmasters believe that this method of enthusing the foremen is going sufficiently far to produce the results desired; that it touches the pride of the foremen and, all things considered, produces a better moral effect than is liable to result from enforced competition; that while the prize system may be productive of immediate results, the incentive to excel lasts only temporarily; and that it is wrong to force human judgment to discriminate minutely as to the work of the foremen where no necessity exists.

The idea that annual or other official track inspections are advantageous to the work of track maintenance seems to be quite deeply rooted with not a few maintenance officers, but of these many men of experience consider that results superior to those which may be had by the giving of prizes may be obtained simply by announcing the findings of the inspection, without awarding prizes, and that in this way good feeling among the men is better maintained. On some roads where this principle is observed the section which maintains the highest standing receives a mark of distinction in the form of a "blue board," on which is inscribed "The Best Section," or words to similar effect. Such a board is also used on some roads where the prize system is in force. Still another class of thinkers favor omitting any mention of the highest standing, but grade the sections into first, second and third classes, according to the ratings of the annual inspection. And still another class think that it answers the purpose sufficiently well to get the section foremen together once each year and give them a trip over the road on an observation car in company with a number of the higher officials, without announcing results. On such a trip the foremen are invited to criticise the track under one another's charge, and as there is no compulsion in the matter of expressing opinion, each man feels a greater freedom in forming his opinions than would be the case if a prize was at stake. In this way the foremen get to see one another's track, get the benefit of one another's criticisms, learn new opinions, and undoubtedly receive a good deal of benefit from the trip. By winding up such an affair with a banquet or something of that sort, with encouraging speeches from the officials, there can be no doubt but that the foremen would return to their work with renewed ideas as to their importance in maintenance-of-way economy, and with more nearly equal satisfaction than would be the case were the foremen to remain at home while the officials make the trip and dismiss the affair with the cold announcement that some foreman had been selected to receive a prize. After all, what does it matter if there be no formal decision, or even united opinion, as to whose track is the best? The philosophers tell us that contest between man and man is not the ideal state of living. Why then should it be considered the ideal condition of labor?

The Unit of Maintenance of Way Organization.

SUPPLEMENTARY NOTES AND TABLES.

196. Tile Drainage.*—In the construction of a tile drain the first thing necessary is to have accurate levels run and true grades established. Too much care cannot be taken in this part of the work, for if the levels are not accurate the best results cannot be expected. In beginning the work it is well to stretch a line in the direction of the proposed drain and then take a spade and cut the earth to this line. The line should then be changed over to the other side of the drain, which should be about 14 ins. wide at the top, and the earth cut to the line in this position. With a drainage spade the drain is then dug down to within about 16 ins. of the bottom, before grade stakes are set.

In setting stakes for grading the bottom my practice has been to first set two stakes 50 ft. apart, one at the outlet and the other further back, or in the direction of the flow of water, and then to wrap an envelope or piece of white paper on each of them at convenient hight. With a leveling instrument I arrange the hight of the envelopes to correspond with the grade of the drain; that is, if the survey calls for a fall of 3 ins. per 100 ft., I place the envelope on the stake at the outlet 1½ ins. higher than the envelope on the stake 50 ft. back. I then take a stake and notch it at a hight equal to the depth of the drain below the top of the envelope on the stake at the outlet. This notched stake I make use of in sighting for the bottom of the finished drain, at intervals of a few feet, the requirement being, of course, to dig the trench to such depth that the notch on the stake, when the latter is stood in the trench, shall be on the line of sight with the top edges of both envelopes. Other means are sometimes taken to maintain a uniform grade, some stretching a line over the tops of leveled stakes along the side of the drain, and then using a pole with a gage arm to reach out to the line and ascertain if the bottom of the trench is at proper depth. One fault with this method is that a damp line on a dry day is liable to sag, and if not carefully watched the bottom of the trench will be finished to correspond with it. In tile-draining a railroad cut where the grade is already established, a survey would, of course, be unnecessary, as reference can be had with the grade stakes or the rail.

The bottom spading is taken out with a round-pointed spade a little over 4 ins. wide at the point, and every little while the drain cleaner, which is a scoop with a long handle that pulls toward the operator, should be used. Under ordinary circumstances one should not get into the bottom of the trench with his feet. With a good drain cleaner in the hands of an expert the bottom of the trench can be shaved off smoothly and nearly as true as a carpenter would plane a piece of board. The trench is now ready for the tile laying and should never be left too long open, as the sides may cave in or clods of earth may fall into it.

In laying tile one should not stand in the trench, since on soft material one's feet will puddle up the bottom and render it unfit to receive the tile. For placing the tile in position, an implement known as a tile hook is used. It consists of a small scoop about 1 ft. long, with a crane neck or shank, attached to a handle about 7 ft. long. This blade hangs not far from a right angle, with the handle, but the angle may be adjusted to suit the user. The blade will easily go inside of a 3-in. tile. The tiles are distributed along the trench within convenient reach of the tile hook, and the man who does the laying stands straddle of the trench and lowers the tiles to place with the hook, giving each length a tap with the heel of the hook, to settle it firmly to place. If the section of tile laid does not make a close joint on top it should be lifted up and pressed against the side of the trench, so that by pushing down the tile will revolve on the hook until a close joint is obtained. If there is much water in the trench a small piece of board should be stood in front of the last tile laid, to prevent obstructions from being carried into the tile. The tile is

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***By courtesy of Mr. Alexander Birss.**

then covered over, first rolling in the material which was taken from the bottom of the drain. No particular care is required in doing this except to see that stones do not drop upon the tile and break it. This is what we call "securing the tile," and the rest of the filling may be done in any manner to suit convenience or to expedite the work, a swing plow being much used in filling in drains in farm practice.

I shall now try to say a few things about tile and explain the working of a tile drain. When tiles are burned they nearly always bend just a little, owing to the fact that one side becomes a little hotter than the other, the side which is burned the most thoroughly being the shorter, and slightly concave. In laying the tile the convex or longest side should be on top, as then an opening will be left in the bottom of the joint—usually about ¼ in. wide. It is through this opening that the water should, and by nature does, enter the drain. Comparatively little goes in at the top. There are many things that seem to have an affinity for water and they will "root" down and enter the tile, and it is always in the bottom that they make their entrance. I knew of a case in Green County, Iowa, where a tile drain was constructed parallel to a hedge of willow trees, 33 ft. distant and 4 ft. deep. The willow roots crept out that distance and entered the tile, completely filling it inside. Sunflowers should not be permitted to grow over a tile drain, as they will soon root down to the tile, enter it from below and fill the interior of the drain full of fine roots much resembling corn silk, which will in a little while effectually choke the drain.

Perhaps the most interesting work to be found in tile drainage is in laying tile in quicksand. In such material many a man has worked hard all day without succeeding in laying a single section of tile that would remain in place; and a man who will not display temper in laying a tile drain in quicksand is too good for this world. The best time to undertake tile drainage in quicksand is after a long spell of dry weather, but one never knows until he is strictly in it how quicksand will act, if once let loose. Ordinary curbing is of little account, as the sand will run into the ditch in spite of it. I once knew of a bad case where boiler iron was secured from the railroad shops and used for curbing, but the pressure was too great even for that. My best success in managing quicksand has been through the use of a sheet iron box about 5 ft. long, without top or bottom or rear end; that is to say, a strip of thick iron plate about 11 ft. long bent into the shape of a long "U." The front end should be rounded, with a handle attached to pull it through the quicksand, and the sides at the rear end are held apart by a strong stay in the form of an arch, which resists the side pressure. Sheet iron is too thin and boiler plate too thick for constructing this implement. In operation the sides of the box stand edgewise and the rear or open end is always kept one or two tile lengths behind the last tile laid, to keep the sand out of the tile while at work, for in bad cases it floats around nearly as freely as water. The box is made wide enough to permit clay to be packed about the sides of the joints and remain undisturbed when the box is pulled ahead. The box is pushed down into the sand until the material can be taken out to the proper depth and then two lengths of tile are laid in the open space and covered over and packed about the sides before the box is pulled ahead again. I have used pieces of plaster lath to lay on top of the tile and keep them even and continuous while covering it over with clay. Filling material must be placed upon the tile as soon as possible, to weight it down, for the tendency of the sand is to lift the tile. A piece of board is kept in front of the tile to prevent the sand from getting into it, but a great deal of sand does get in and cannot be prevented. If the tile is laid to uniform grade, however, there is no danger that the drain will become seriously obstructed. When working in quicksand the drain should be opened but a short distance ahead of the tile that is being laid, especially if close to the track, as in that case the pressure from passing trains might cause the trench to cave and undermine the track. For the same reasons the drain should be filled in and finished as close as possible to the work of laying the tile.

Collars on tile joints interfere with the entrance of water at the natural inlet—the bottom of the joint. I have sometimes laid a 1x6-in. fence board on a soft bottom which would not carry the tile, but except in a case of this kind a board under tiling is not a good arrangement. The accuracy with which the tile is laid has an important effect on the capacity of the tile drain; as for instance, if there is a sag of one inch the tile will fill up that much and its capacity will be reduced; and, of course, the same result must be expected where one or a few lengths of tile are laid an inch too high. To do a first-class job in laying tile is indeed a fine piece of work.

197. Some Details of Steel Working and Departures in Rail Design.—During late years various experiments have been made with the intention of adopting radical departures in steel rail manufacture. In order to understand these experiments and the reasons therefor, it is essential to comprehend some of the elementary facts embraced in various processes of steel production. To such as may not be familiar with the metallurgy of steel the brief exposition which follows may be of some assistance.

Steel used for construction purposes generally is manufactured by either of two processes, the Bessemer or the open-hearth. The object of either process is to regulate the amount of carbon and other alloys found in the cast iron. In the Bessemer process this regulation is effected by forcing small streams of cold air through the molten metal, which is poured into, and held in, a large iron pot called a converter. The presence of the air within the mass of the heated metal oxidizes or burns out the carbon, silicon and manganese. The process may be arrested at the point where the desired percentage of carbon has been reached (Swedish practice), as indicated by the appearance of the shower of sparks issuing from the converter, but in the largest practice it is continued until all of the oxidizable elements are burned out (as indicated by the appearance of the flames), when melted spiegeleisen or ferro-manganese, containing known proportions of carbon, manganese and silicon, is added to recarbonize the iron. In the latter practice better control is had in proportioning the alloys.

In the open-hearth process the regulation of the alloys is effected by the action of an oxidizing flame from a coal fire in a reverberatory furnace, or from heated gases in a regenerative gas furnace, the latter type of furnace being the more common. The iron is usually melted in this furnace. In the open-hearth process the carbon is not all burned out, as it usually is in the Bessemer process, for the oxide of iron formed while the cast iron is being melted down forms a slag over the bath of molten metal and protects the iron, carbon and silicon from further oxidation; in the meanwhile, however, the carbon and silicon have become partly consumed. It is also possible to introduce foreign slag or to vary the proportion of oxygen in the flame, so that the metal can be held in the fused state without considerable change until samples can be taken from the furnace and tested, to determine the extent of decarbonization. These tests are simple, and quickly made, consisting merely in dipping out a small quantity of melted iron in a ladle, when a casting is made, cooled and broken. By observing the fracture an experienced operator can estimate closely the carbon ingredient. The usual method of reducing the percentage of carbon is to introduce uncarbonized metal in the form of wrought iron and steel scrap in sufficient quantity to produce the desired mixture, but in any case the proportioning of the alloys is well under control, there being plenty of time to introduce modifications. Excess of carbon may be removed by charging oxide of iron in the form of ore, to supply oxygen for further decarbonization, or, in time, as the temperature rises, the carbon will combine with some of the oxygen of the iron oxide slag which becomes mixed through the mass by ebullition from escaping gases. This action restores some of the iron of the oxide to the metal product. To remove the remaining iron oxide of the slag spiegeleisen rich in manganese is charged, the manganese uniting with the oxygen of the slag and restoring the iron of the oxide to the bath. In case the percentage of carbon should at any time be found too low recarbonization is readily effected by adding cast iron.

It may now be explained that in the ordinary manner of operating a Bessemer converter or an open-hearth furnace, as above described, a sand or (acid) silica lining is used and the product is known as acid steel. The open-hearth process of making acid steel is sometimes called the Siemens-Martin process. The fact of particular significance about the production of acid steel is that no phosphorus or sulphur is eliminated—and this applies to both the Bessemer and open-hearth processes. This means that in the production of acid steel of good quality only ores that are comparatively low in phosphorus and sulphur can be utilized; hence the terms "non-Bessemer," as applied to ores high in these elements, and "Bessemer pig" as applied to cast iron which is comparatively free from them. The removal of an excess of phosphorus and much of the sulphur, thus making cheap ores available, may be effected by fluxing the steel with lime, which unites with the phosphorus and carries it off in slag. As, however, this slag will attack and chemically destroy a silica lining it becomes necessary in dephosphorizing to equip the converter or open-hearth furnace with a basic lining, which usually consist of lime, as found combined in magnesite or dolomite, made into bricks or applied in some other form. Steel produced in this manner—whether in a Bessemer converter or in an open-hearth furnace—is known as basic steel. In the basic Bessemer process the elimination of the phosphorus by reaction between the charge and the basic substances takes place during the "afterblow"; that is, the blow is continued after the complete oxidation of the carbon, instead of terminating it on the drop of the carbon flame, as in the acid process, and the very high temperature then causes the phosphorus to combine and separate. As there is no pronounced indication of the elimination of the phosphorus, the duration of the afterblow is to a large extent regulated by the judgment of the operator, who stops the blowing when he thinks it has continued for a sufficient time. Tests are then made and if the amount of phosphorus is too great the blow must be renewed.

The chief distinction between acid and basic steel is therefore the elimination or the partial removal of phosphorus in the latter. As between the two the basic process, although adapted to the use of cheaper ores, is the more expensive. Basic linings are less durable than acid linings and the basic process wastes more pig iron than the acid process. Moreover, the basic Bessemer process requires a special iron ore which must be low in silicon and comparatively high in phosphorus. The adaptation of the process to high phosphorus ores is therefore to some extent limited. In England there is a by-product from the basic process which is used as a fertilizer. It sells for about $1.00 per ton.

As between the Bessemer and open-hearth processes, the Bessemer is the cheaper, but the open-hearth is generally considered the more reliable. Open-hearth steel is considered to be more uniform in composition or more homogeneous than Bessemer steel. Whatever differences may exist in this respect are explainable on the fact that open-hearth steel remains at all times during the process of manufacture more thoroughly mixed with its alloys. As the carbon is not all burned out, and seldom burned to a percentage lower than that finally retained, the distribution is not seriously disturbed. On the other hand, in the ordinary Bessemer process the entire carbon component must be added to the metal after the blowing of the metal has ceased, and the only mixing operations to which the metal is afterward subjected is when it is poured from the converter into the ladle and drawn from the bottom of the ladle into the ingot molds. Some think that these operations do not sufficiently agitate the metal to secure a uniform distribution of the carbon and that injurious segregation is liable to occur. At any rate it is not an uncommon experience to find widely varying physical properties, and even chemical composition, in test pieces cut from different parts of the same piece of Bessemer steel. Mention of a single instance will serve to illustrate possibilities. Chemical analysis of a sample taken from the point of fracture on a broken rail showed the following variations from the average composition of the heat, the latter being mentioned first in each case: Carbon, 0.45 to 0.61 per cent; phosphorus, .09 to 0.20; sulphur, .076 to 0.22; manganese, 0.93 to 1.03. As already explained, the opportunity to test open-hearth steel at any stage of the process, while such cannot be done with the Bessemer product, carries the general impression that the former is under better control.

Comparing the expense of the two processes, the open-hearth plant is the cheaper, but the longer time required to produce a given output by this process very much augments the cost for labor. The capacity of Bessemer converters in ordinary use runs from 5 to 17 tons, 10 tons being perhaps the capacity most commonly found. In a converter of this size the 10 tons of metal is usually blown in about 15 minutes, which includes the time between pouring the metal into the converter and pouring it out into the ladle. With metal which is low in silicon a heat is sometimes blown in 8 or 10 minutes. Speaking in a broad and general way, a Bessemer plant of two converters will average about 160 blows in 24 hours. The time of blowing a 15-ton converter is a little longer than one of smaller size. Open-hearth furnaces are built of all capacities from 10 to 60 tons per heat, although for special purposes there are some in operation of smaller capacity. In American practice 30 and 40-ton furnaces are perhaps the most commonly found. The time required to work a heat in an open-hearth furnace is 8 to 12 hours, depending upon the strength of the blast and variations in the raw material. In ordinary American practice an average of about 16 heats are worked per week.

The unsatisfactory service from the metal in rails made during recent years has turned the attention of railway men and manufacturers toward basic steel. Both basic Bessemer and basic open-hearth steel rails are used in Europe, but in this country basic steel rails have been used but little, and then only by way of experiment. In 1896 the Northern Pacific Ry. laid 2000 tons of basic open-hearth steel rails, of the following composition besides the iron: carbon, 0.65 to 0.75 per cent; silicon, 0.10 to 0.16 per cent; manganese, 0.65 per cent; phosphorus, .03 per cent; sulphur, .05 per cent. At the first reweighing the results apparently indicated a rate of wear hardly exceeding one third of that of adjacent Bessemer rails laid at the same time, in which the carbon is not in excess of .50 per cent. The Baltimore & Ohio R. R. also has experimented with basic open-hearth steel rails, laid on curves alternately with rails of Bessemer steel. Comparison of results after 20 months of service under heavy traffic showed that on the low side of the curve the rate of wear for the Bessemer rails was about 62 per cent greater than for the open-hearth rails; on the high side of the curve the rate of wear for the Bessemer rails was about 50 per cent greater than for the open-hearth rails. The wear of both kinds of rails on the low side of the curve (elevation 4 ins.) was about double the amount on the high side. The lateral wear on the high side was not abnormal for either kind of rail. The Pennsylvania R. R. has experimented with small lots of open-hearth rails laid in the same way. The composition is as follows: Carbon, 0.55 to 0.72 per cent; manganese, 0.72 to 0.79; silicon, 0.09 to 0.12; phosphorus, .03 to .06 The Louisville & Nashville R. R. has extended its rail specifications to cover basic open-hearth steel. The following tabulation contrasts the chemical composition of the two kinds of metal for 80-lb. rails:

	Acid Bessemer.	Basic Open-Hearth.
Carbon	.55 to .65 per cent.	.62 to .67 per cent.
Silicon	.15 to .20 per cent.	.10 to .20* per cent.
Manganese		.90 to 1.00 per cent.
Phosphorus not to exceed	.085 per cent.	.05 per cent
Sulphur not to exceed	.07 per cent.	.05 per cent.

* .15 per cent preferred.

The Talbot Process.—As already shown, both the open-hearth and Bessemer processes are subject to certain disadvantages. The open-hearth furnace in ordinary use is too slow of operation to produce rail steel at an economical price and besides this its output is intermittent and not well adapted to the continuous operation of a rail mill backed by a convenient number of furnaces. On the other hand, the Bessemer converter is wasteful of metal, the loss of pig iron being usually about 13 per cent when converted into acid steel and 17 to 19 per cent if converted into basic steel. In an open-hearth furnace the loss of pig iron varies from five to eight per cent. These considerations have made it desirable to devise some means of manufacturing steel which would give the continuous production of the Bessemer converter and reduce the loss in metal to or below that of the open-hearth furnace. One effort in this direction which is now receiving a good deal of attention is a new method of producing open-hearth steel continuously, known as the Talbot process, from the name of the inventor, Mr. Benjamin Talbot.

This process was first worked at Pencoyd, Pa., in 1899, where a 75-ton furnace of the tilting type, with basic lining, was set up. As there are no blast furnaces in this vicinity the pig iron is melted in cupolas, and the first charging of the furnace, which takes place on Sunday evening, is made with about 50 per cent of melted metal and 50 per cent of scrap. This heat is worked down to steel with ore and lime in the usual way, and when the bath has reached the proper condition the furnace is tilted and about one third of the metal is poured off through a tap hole lower than the top level of the bath, so that no slag is run off. This metal is poured into a ladle and cast into ingots. Oxide of iron in a finely divided state is then added to the slag, and as soon as this is melted, about 20 tons of molten cupola metal is poured in to replace the steel tapped out. The bath then begins a vigorous boiling, much resembling the blowing of a Bessemer converter, and the carbon of the newly added metal is rapidly burned out, the fuel gas being meantime cut off from the furnace. The high heat developed by burning the carbon of the metal with the oxygen of the slag supplements the effect of the fuel gases and there is an economy in fuel and operation over ordinary open-hearth practice. In the course of 10 or 15 minutes the slag, which by this time has lost most of its iron oxide, is partly poured off and by the addition of iron ore and lime the bath is worked down to finished steel, when about one third of the steel is again tapped off. The foregoing operations are then repeated and kept up during the whole week, the furnace being completely emptied on Saturday, for repairs. In this manner a regular supply of steel at frequent intervals is obtained, with all the advantages of the open-hearth process and none of the disadvantages of that or the Bessemer process. Not only is waste of pig iron avoided, but the yield is actually increased from six to eight per cent of the pig iron poured into the furnace for conversion, the gain being due to the direct reduction of the oxides added in the form of iron ore. Each furnace will cast about 30 heats per week.

The Bertrand-Thiel Process.—The Bertrand-Thiel process of steel making, now being promoted in England, bids fair to work some changes in rail manufacture. This process consists in refining pig iron by two successive operations in basic-lined furnaces worked in pairs. The molten iron is poured into the primary furnace at a comparatively low temperature, and by additions of iron ore and lime about 90 per cent of the phosphorus and silicon, most of the manganese and 30 per cent of the carbon are eliminated, in the course of three hours, the phosphorus uniting with the lime to form slag and the carbon being burned out by the oxygen set free from the ore. At this juncture the bath is tapped into the secondary furnace, which has previously been charged with scrap and brought to an oxidizing heat. The primary furnace is usually set at a higher level than the secondary or finishing furnace, so that the transfer of metal takes place by gravity. During the transfer the slag is skimmed and run off. The removal of the slag protection causes the further oxidation of the carbon from the iron, in the secondary furnace, where the components can be regulated at will, adding spiegeleisen if necessary. After further treatment of about three hours steel of any desired quality can be obtained. Either all pig, or part pig and part scrap can be used. In the former case the process shows a gain of 2 to 3 per cent in yield on the pig iron charged, owing to the direct reduction of iron from the ore. The slag, being highly phosphoric, is a valuable fertilizer and sells for a good price. Eight heats can be worked every 24 hours from each pair of furnaces, which can be made of any capacity convenient for open-hearth work.

Nickel-Steel Rails.—The hardening and toughening effect of alloying steel with nickel, so successfully practiced in the manufacture of armor plate, has naturally suggested a like treatment for experiments with rail steel. Such experiments are now being conducted on a small scale with steel made by both the Bessemer and the open-hearth processes. On the Cleveland & Pittsburg division of the Pennsylvania Lines West some nickel-steel rails were laid on a 5-deg. curve, and after four years' service were said to be wearing better than rails of ordinary steel. Another quantity of nickel steel rails was laid in the west-bound track at the Horse Shoe Curve, on the Pittsburg division of the Pennsylvania R. R. These rails are of 100-lb. section and were rolled in an order of 300 tons, the metal being handled by the Bessemer process. Owing to "red shortness" the actual output was only 277 tons of rails, and 57 tons of these were of second quality. Following is the average chemical analysis: carbon, .504 per cent; phosphorus, .094 per cent; manganese, 1 per cent; nickel, 3.22 per cent. In the straightening process the rails showed much greater rigidity than is developed in the cold-straightening of ordinary steel rails. The rails were also found to be very hard, so much so that ordinary drills were not found equal to the work of drilling the bolt holes. The price of these special rails is said to have been very high. These rails have given good satisfaction from the standpoint of wear. Some of them laid alternately with ordinary Bessemer steel rails on 6-deg. curves had shown but little wear in four years, whereas the regular rails in service the same length of time had been turned and become considerably worn on the other side of the head. The result of these experiments was the placing of large orders for nickel-steel rails by the Pennsylvania R. R. and the Pennsylvania Lines West, in 1903, for further trials. At that time the Baltimore & Ohio R. R. began to experiment with these rails. These various orders were rolled by the Edgar Thomson Works of the Carnegie Steel Co. The angle-bar splices were also rolled from nickel-steel, the nickel content for both purposes being 3¼ to 3½ per cent. It has been proposed that trial should be made of frogs and crossings made of nickel-steel rails, to determine whether such material might not be found more serviceable for the purpose and more economical, notwithstanding the higher price. More recent progress with nickel-steel rails is mentioned in Sec. 220.

Wheeler-Process Rails.—The Southern Pacific Co. has made trial of rails rolled by the Wheeler process, whereby two grades of metal are so manipulated that the outer or wearing surfaces of the rail are of very hard high-carbon (0.785 per cent) steel, with a soft steel core (0.476 per cent carbon). The core occupies about half of the space in the head and flange and nearly all the space in the web. During 1897 thirty-nine of these rails were laid on the outside of curves in three places, 30 being on 10-deg. curves and 9 on a 5½-deg. curve; and after a service of a little more than 3 years, under traffic of 12 to 15 million tons, the rate of wear of the Wheeler rails was found to be just about half that of rails of ordinary steel of same weight and pattern laid immediately adjoining them on the same curves. These rails were traversed by the heaviest mountain locomotives of the road. During the three years 11 of the 39 rails failed by pieces of metal breaking from the side of the head, and had to be removed. The manner of failure indicated an imperfect union between the hard and soft steel.

The Manning Unsymmetrical Rail.—Mr. W. T. Manning, consulting engineer of the Baltimore & Ohio R. R., is the designer of a rail with an unsymmetrical head, conceived with the idea of prolonging the life of the rail on the outer side of curves. The section differs from that of ordinary rails in having an excess of metal on the gage side of the head, thus interposing additional metal for wear. Experiments with rails of this design are being tried on the Baltimore & Ohio and Pittsburg & Western roads. The form of section is illustrated by Fig. 15A, in which $A\ B\ C\ D$ represents the American Society section and $A\ H\ G\ J\ C\ D$ the Manning section. The excess material includes, therefore, some metal added to the top of the rail, as well as to the side of the head. In 85-lb. rails the distance BH is ¼ in., and the vertical portion HI is ¼ in. in length and runs into a curve of 1 in. radius extending to the lower corner of

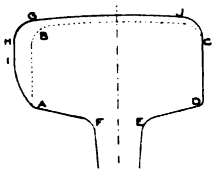


Fig. 15 A.

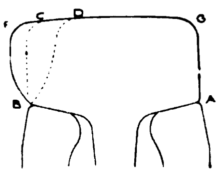


Fig. 15 B.

the head. The intention of the latter feature is to delay a full flange contact as long as possible while the side of the rail head continues to wear away. In a comparison of the two sections with respect to wear of head the limit of abrasion is based upon the state of wear when the wheel flange cuts the angle bar. Referring to Fig. 15B, in which the "Society" section is represented within the lines $BCDGA$, it will be seen that the "Society" section is limited for flange wear to the portion BCD and the Manning section to BFD, thereby prolonging the wear in such proportion as BFC stands to BCD, which is calculated to average 66 per cent. The distribution of metal in the 85 and 90-lb. sections is, head 45 per cent, web 20 per cent and base 35 per cent. The excess metal amounts to about 3 lbs. per yard or 2½ tons per mile of rail. Another advantage in the use of this rail, said to have been shown by experience, is that, owing to the excessive bearing on the inside of the rail, the track has a greater tendency to hold to gage than is the case with rails of symmetrical section.

The first experiment with these rails was with 1000 tons of 85-lb. section laid on heavy curves in the mountains in sections adjacent to rails of American Society section of the same weight and material. After a service of 16½ months at some points a comparison of results showed up very favorably to the Manning rail. In that time the rails of the American Society section had worn away to the angle bar limit, thus rendering them unfit for further service, whereas the wear on the Manning rails had reached only to a point which would correspond to the gage line of the top corner of the American Society section. In ultimate wear these results indicated a service 125 per cent greater for the Manning section than for the American Society section on curves.

198. Material Yards in Track-Laying.*—The location of material yards and the handling of the material on new lines depend a great deal upon the conditions under which the work is done. It is a very different matter in laying track on some new road that is being built in ten-mile stretches, where it is necessary to finish the first ten miles in order to pay for the grading of the next ten miles, from what it is on a long road where the work progresses continuously. Then, again, there is the small company that gets only a few cars of rails at a time, and begins to operate its road before it is built. (In this connection I have seen a road put on trains to do local business when some of the track was only half tied and only two or three ties spiked to a rail—track that I would not advise running a construction train over at any considerable speed.) For a road that gets only a little material at a time and is a long time building, and where only a few miles of track are laid each month, no special rule can be laid down for placing material yards or for handling the material trains. For short lines of this kind but little need be said about the material yard, except that what little material is to be stored should be unloaded with as much regularity as possible.

Where long lines are being built the material yard should be planned out in advance, and the material should all be unloaded according to this plan and with the object in view that it will have to be reloaded, probably in a hurry, and that a delay to the track-laying force for an hour will amount to as much as, or more than, the wages of the unloading gang for an entire day. The mistake usually made is at the very first in not providing sufficient room, by laying out side-tracks, to hold the material. Never unload any material off from the main line, either the new main line or the old one, and especially the old one. Never unload material off from a side-track on the old main line that is being used to operate the old road. Never unload material off from a Y-track, either old or new. Never unload material into borrow pits or off from a high fill; and, above all things, never unload the cars just where the freight train happens to set them, unless it is the proper place. Never send a young man out from the engineer's office to "pick up a few men and get those cars unloaded as quick as possible." Never send a section foreman on the operated road to unload material for the construction or engineering department unless you tell him what you want done, and how.

In level country a satisfactory material yard can be easily planned and quickly and cheaply laid out. The number of tracks and their location will, of course, depend upon the conditions at hand, but have at least two side-tracks. It is well to have at least two side-tracks on the same side of the main line, about 12-ft. centers for about 300 ft., when the outer track should swing out farther away from the first. At least one of the tracks should be connected at both ends, and if any of the tracks are to be "stubs" or "spur tracks" (which, for temporary use are about as good as any), the switches should be at the end opposite from the direction in which the track is to be laid—that is, if the road is to be built towards the west the switches should be at the east end of the yard. As many tracks should be laid as may be necessary to hold all the material that may be on hand at a time. Temporary tracks can be laid with about 12 ties to a rail, and should be surfaced up only as much as may be necessary in order to prevent the rails from being bent. In other words, don't go to the expense of laying a full tied, full spiked, full bolted and surfaced track for a temporary one.

In unloading the ties pile them at right angles to the track and in not more than two piles on one side of the track. Do not carry them away off, 25 to 100 ft. from the track, and do not pile them up in cribwork style, half one way and half the other. This is sometimes done with the idea of letting the air get at them to dry them out. Rails should always be unloaded lengthwise the track, and do not unload one car-load "here" on a couple of ties and another car-load "there." I saw, in one instance, 85-lb. rails piled up 10 or 12 ft. high, with every other layer at right angles to the track. The cost of unloading them must have been ten times as much as it would have been to have done it right. It took 20 men to load them and it required twice as long to do it as it would have taken ten men if they were unloaded properly. Rails should not be unloaded and piled up close to the track when there is plenty of room, but as far out from it as possible without going beyond the point where a 30-ft. rail can be used for a skid to unload and reload them. By doing this the piles can be

*By courtesy of Mr. John Smith.

made about 50 per cent higher than if the rails are piled close to the track, and they can be reloaded in half the time with a smaller force than if they are piled close to the track. Four men will skid up rails from this pile about as quickly as ten or twelve men will load them when they are close to the track. Angle bars as well as the spikes and bolts should be unloaded near the rails. A cribwork of ties with a floor of ties or crossing plank about 2 ft. above the track should be made and the kegs unloaded on this. If the material yard is on a grade put the spikes etc. at the down-grade end of the piles of rails, so that after a car is loaded with rails it can be started with a bar and run down opposite the "trimmings" (spikes, bolts, and angle bars). I have seen a few very nice examples of this arrangement.

I might say that a well arranged material yard is something that is seldom seen, and that, except on the long western lines, where men have learned from experience, material is seldom unloaded correctly. One great mistake, for a small matter, is to place kegs of spikes or bolts on the ground and a thousand feet or more from the rails. I might explain in this connection, even if partly by repetition, that each car of rails should be "trimmed" when loaded; that is put on all the angle bars for the rails and usually all of the spikes, bolts and nut locks necessary for them. The exception in the latter case is where a "spike car" is used in connection with the track-laying. When the last method is practicable it is about the best, in my opinion, the spikes for the "back work" then being carried on a separate car and distributed from this car as may be required. At one end of this same car there should be carried crossing plank and surface cattle guards, when the track force is putting them in. What I mean by properly unloading spikes and bolts is that they should never be rolled into borrow pits or be placed several feet below the level of the track; and they should never be unloaded directly on the ground, as the dampness, caused by rains etc., will rot the kegs and rust the bolts. The practice of unloading them low down, off a fill, will also cause the kegs to be broken, so that they cannot be reloaded. Always build a platform with a cribwork of ties about half the hight of the floor of the car. It will pay, as it will save breaking the kegs in unloading upon it, they are easily reloaded, and moisture of the ground will not affect them. It is my observation that many men unload track materials with only one idea in mind, and that is to get them off the cars with the least amount of work and trouble and to unload every car wherever the train happens to leave it. For example, in a material yard I have in mind, the spikes and bolts were unloaded at the west end of the material side-track, while the rails were unloaded at the extreme east end of the yard, 1-3 of a mile from the spikes, with 30,000 or 40,000 ties piled up along the track in between them.

All material loaded in the material yard should be loaded properly. When curved rails are being laid they should be curved before loading them to go to the front; and don't forget to curve just enough "short rails" for them, and don't load the short rails all on the bottom of the car under the rest of the curved rails—place them on top, as it is then easier to get at them at the front; otherwise it is necessary to "dig" for them when wanted. In laying right and left-hand rails, that is, using a certain side for the "running" side, as when laying old rails, for example, arrange them on the cars so that they will unload properly. Where the Harris track-laying machine is being used they may be loaded on the right and left-hand sides of the cars, but for other track-laying machines, where the rails are all run forward on one side of the train, it is necessary to load the rails for one side of the track on one car and the rails for the other side of the track on another car, alternating the cars loaded with right and left-hand rails. It is then always necessary to bring out the cars in pairs.

Personally, one of the best material yards I ever saw was at Fremont, Neb., in 1887, where the material for more than 100 miles of track was piled up. We laid this track by contract, and on only one instance was the "front" delayed for failure of the prompt delivery of the material to the last side-track, and, as a rule, we laid more than two miles of track per day. An excellent illustration of modern practice in handling material for long stretches of track-laying, especially in the West, was afforded in the methods employed by the Burlington & Missouri River R. R. in the Guernsey extension, in 1899 and 1900. The same practice was also employed not only on previous extensions of this same company but on other western roads where there was considerable work to do from one point. The material yard on the Guernsey (Wyo.) line was located at Alliance, Neb., the point where the new work started. When the work of laying track started there were vast quantities of ties unloaded and piled up, not promiscuously here and there, but all in one place, along two or three "tie tracks." The rails were unloaded along both sides of a track used only for that purpose. The man who unloaded them did so with the idea that it would be necessary to again load them, and he did it right.

On this extension (as is the practice on most of the western roads in laying new track) the telegraph wire was brought up to the end of the track every night and an operator was employed, so that all reports and orders could be sent in daily. The speed of track-laying was about 1¼ miles per day. The supply train left the material yard at Alliance each evening at about 7 o'clock, carrying material for the next day's track-laying. The selection of the late hour for leaving was to give opportunity to send in special messages by wire late in the day and have the things ordered brought out to the front the same night. In making up this train the cars loaded with the material for the next afternoon's work were placed ahead, with the cars carrying material to start the work in the morning coupled in at the rear of the train. The purpose of this arrangement was to save switching at the farthest side-track, or the point where the material was left, as the car-loads of material for the morning's work were then pushed in at the rear end of the side-track, in position for "first out" in the morning, leaving the other division of the train on side-track to be taken out after noon. This arrangement of running the supply trains at night also afforded the best economy in the use of cars, as the cars unloaded at the front during any certain day could be returned to the material yard in time for reloading early the next morning. The ballasting of the track followed close upon the track-laying, so that the material trains were able to make good speed.

199. Rules on Care of Lamps, A., T. & S. F. Ry.—The following are the rules of the Atchison, Topeka & Santa Fe Ry. issued to all employees using or caring for signal and all other oil lamps:

1. Standard headlight oil, as furnished by the company, must be used in all signal lamps, except hand lanterns. Signal oil is furnished for lanterns only. No attempt must be made to improve the quality of signal oil by adding lard or kerosene oil. Signal oil is rendered explosive if the lard and kerosene oils are mixed in the wrong proportions. If the oil does not give satisfaction the trouble must be reported.

2. Lamp fonts must not be filled above a point at least ½ in. below the top of the font.

3. The wick must be long enough to touch the bottom of the font, and must fit in the burner properly. Wicks that will not move freely by turning the ratchet shaft are apt to clog the burner, preventing a free flow of oil to the flame, causing the burner to overheat, encrust the wick, give a smoky flame, and sometimes cause an explosion.

4. When the ratchet wheels will not properly raise or lower the wick, the wick should be drawn up through the wick tube with the fingers, and then moved back to place by the ratchet wheel. If a wick is too large for the wick tube it can be reduced by drawing out a few threads.

5. The wick must be kept below the top of the burner when lamp is not lighted, to prevent oil flowing from the wick over outside of font.

6. All lamp fonts must be emptied and drained once every week and refilled with new oil. At points where a number of lamps are used the old oil thus removed must be poured into a can kept for that purpose, and marked "Old oil only." When filled, this can must be sent to the nearest roundhouse or car-yard, and the oil used for such purposes as cleaning trucks etc., but on no account must it be used for lamps again.

7. Once a month all oil cans and lamp fonts must be thoroughly rinsed with clean boiling water and then thoroughly drained and dried. Soap or soda must not be used in the water, as they will leave a residue or coating on the font or can that is injurious to the oil.

8. Lamps must be cleaned, fonts filled, wicks trimmed and burners cleaned daily. All vents in lamp body must be kept open and clear of soot and dirt, so that lamp will receive the proper amount of draught. Special attention must be given to the lenses to keep them clean, and to the top of lamps where the soot is most likely to collect. Lenses must be kept clean of all grease, oil, soot or dirt. If they cannot be cleaned in the lamp, lenses should be removed, cleaned with clean boiling water, care being taken to remove all grease and soot from the corners and angles on the corrugated back of lenses.

9. If the burners become fouled with oil, soot or incrustations from the wicks, they can be cleaned thoroughly by dipping in boiling water. The gas escape vent in the burner must never be allowed to become closed.

10. All lamps should be lighted for a short time before turning the flame up to its full hight, which should not be more than one inch above the top of burner. All lamps should be examined after fonts are put in place to see that they do not smoke.

11. The sulphur must be burned off the match before it is applied to the wick, to avoid encrusting the wick with sulphur.

12. In no case will employees be allowed to make alterations in lamps. If they do not give satisfactory service the trouble must be reported.

13. When a lamp through any cause becomes unserviceable a requisition must be made for a lamp to replace it, and as soon as the latter is received the defective lamp must be sent to the general storekeeper with a "Defective Lamp Report" (Form No. 872), properly filled in and attached to the lamp as a shipping tag. The stub of this report must also be filled in and mailed to the lamp inspector at the same time, care being taken to quote the requisition number on which the lamp to replace the defective one was ordered.

14. In taking down or replacing lamps at semaphores, the glasses in the semaphore arm spectacle frames must be inspected to see if they are clean and in good condition. A broken glass must be reported by telegraph to the trainmaster and the signal engineer.

200. Distributing Ties.—(By courtesy of Mr. J. C. Rockhold.) The varying conditions which one has to contend with when distributing ties for renewal make it practically impossible to follow any set rule, or method, as that would call for equally set conditions. For instance, it often happens that, on account of heavy commercial business, we find ourselves short not only of suitable cars in which to load the ties, but power as well. Under such circumstances the ties come dragging along in small lots, and we are not justified in organizing a work train for this work. In such cases as it is necessary to release the cars without delay I have been in the habit of using the local freight trains and one or two gangs of section men, or enough to put four men to the car if we were handling oak, treated pine, or water-soaked ties; or if seasoned redwood, or dry, untreated pine, then two men to the car are sufficient.

When ordering ties for renewal I always make it a practice to go over the ground personally with the foremen, marking each tie with an adze which it is found necessary to remove; and whenever possible to do so, I make it a point to superintend in person the distribution of the ties, as I have learned from experience that it is not safe as a rule to rely too much in such matters on the average foreman's judgment. He usually errs in favor of his own particular section, or if he is an extra foreman, his chief object is to get the ties unloaded. Whether he gets too many or not enough ties off in certain limits, whether they lie at the top or at the bottom of a 30-ft. embankment, are matters which chiefly concern the man who puts them in the track, and for this reason are a secondary consideration with him. A great deal of the expense of renewing ties may often be traced back to careless or slipshod methods of distributing. Except in the case of high, narrow fills, narrow cuts, or tunnels there is no good reason why ties should not be so distributed that the push car need never be brought into service. I always unload the new ties on one side of the track and take out the old ties on the opposite side. In this way the men do not have to climb from one side of the train to the other when loading up the old ties for fuel, fence posts etc.

Whenever practicable, ties for renewals should be unloaded on a face. If this is not done, when the gaps are finally closed up there is generally a shortage or a surplus, and either these places are left short of ties or else more are unloaded than can be used, and later on have to be redistributed. This takes time, and this is one of the cases where time is money. Again, unless ties are distributed on a face it is a difficult matter to get an accurate check of the number unloaded from each car. This results in no end of trouble for the office force.

The size of the crew used for unloading depends: first, on the grades, and the number of cars the engine can handle; second, upon the distance between side-tracks; and third, upon the number of trains to contend with. But, suppose conditions are normal: i. e., plenty of power, no lack of equipment, and ties coming along regularly. I find it is then preferable to do the unloading with a regularly organized force, and work train. The reason for this is obvious:

they soon become expert in the work of "opening up the cars" and handling the ties, and will easily unload a third more in a day than men who are not accustomed to the work. As a general proposition it is best to handle short trains, say ten cars, as you can start them quickly, stop them exactly where wanted, make good time getting out of the way of trains, and a very short siding will hold them. My plan is to put either two or four men in each car, according to the kind of ties being handled, as already explained. I find how many rail lengths this particular train covers before leaving the station, stop the train one train length short of the point where I intend to begin unloading, and while the men are "opening up the cars" go ahead and count the number of ties that are to be taken out in the number of rails covered by this train. I then divide this number by the number of cars in the train, the result being the number of ties to be unloaded from each car. By a prearranged signal I apprise the foreman how many ties I require from each car, and he in turn communicates it to the men. The train is then moved forward and while the men are unloading I again go ahead and count the number of ties to be removed from the required number of rails, and again signal the number to the foreman. The train is again moved forward one length.

This plan is pursued until the cars are all empty. Should one car become empty before the others, as frequently happens, count the full number of rails covered by the original number of cars in the train, but in the division reduce the number of cars one or more as the case requires, which will of course raise the number to be unloaded from the remainder accordingly. The advantages of this plan are as follows: First, each man has to do his share of the work, as there is no possible opportunity for shirking if one was so disposed; second, any number of cars can be unloaded without confusion, and an accurate check can be kept on each car; third, you get just the number of ties unloaded you require—no more, no less.

201. Tie Preservation in Europe.—In Europe, particularly in England, France, Germany and Austria, where lumber is generally high in price, the preservation of railway ties by chemical treatment has been practiced longer than in this country, and more scientifically. In the first place, the timber that is cut into ties is more carefully selected there than here, and the ties are bought to closer specifications. After that more attention is paid to natural seasoning than is the rule in this country. The ties are carefully piled and allowed to season 6 to 18 months before treatment. An allowance of 8 months to a year for seasoning is quite general practice. And then the ties are more carefully handled in other ways; as, for instance, measures are taken to prevent splitting and checking, which has never been done in this country. If ties exposed to the sun show signs of checking or splitting at the ends they are bored and bolted, to draw the fibers together, or S-clamps are driven into the ends. The latter device consists of a piece of sharpened hoop iron or bar of edge-tool section, ⅝ or ¾ in. wide, bent into the form of a double hook or letter "S," in sizes 3 to 7 ins. long. Ties piled for seasoning are frequently inspected, and wherever there is an indication of incipient cracking one of these clamps is driven into the end of the tie, across the line of cleavage, to hold the fibers together and prevent them from opening further. Beech ties, like chestnut and some varieties of oak in this country, are especially subject to checking. And then in Europe ties are generally adzed at the rail seats, if necessary, and bored for the spikes, by machinery, before being treated. In connection with boring holes for the fastenings at the time the ties are treated, it is found that the gage can be established with greater precision than results when boring the holes at the time the tie is placed in the track. If screw spikes are used the spacing of the holes bored in the ties does not vary, the widening of the gage for curves being provided for by means of adjustable clips or adjustable gage pieces in the fastening for the tie plate.

The antiseptic most largely used for tie treatment in Europe is coal tar creosote. Of 87 railways reporting to the International Railway Congress in 1900, 28 were using untreated ties and 59 had adopted some process of treatment. Of these 59 roads 38 were using creosote, 18 were using zinc chloride, four were using zinc-creosote, three were using copper sulphate and one was using brine. Five were using two processes. In Great Britain the creosoting process is used exclusively, and practically all the ties are treated. The timber is imported Baltic pine (also known as redwood and Scotch pine) from Norway, Sweden and Russia. The ties are injected with 7 to 9.6 lbs. of coal tar oil per cubic foot, and the average life is 15 or 16 years. The average life of the untreated tie is about 8 years. In France about 60 per cent of the ties are oak, 22 per cent beech and 18 per cent pine. The beech is native wood, the oak mainly so (some of the supply being obtained from Italy), and the pine is imported. The use of oak is diminishing and the use of beech and pine increasing. Creosote in large quantity is the antiseptic chiefly used, but zinc-creosote is used on the state railways. All of the beech and pine and nearly all of the oak ties are treated. The oak ties take from 9 to 13 lbs. of creosote each and the beech and pine ties generally 35 to 60 lbs. each. The standard tie is 8.53 ft. long, 5.1 ins. thick and 10.2 ins. wide. The Eastern of France and the Paris, Lyons & Mediterranean roads inject 60 lbs of oil per tie, for beech wood, and the Western Ry. 44 lbs. per tie. The life obtained is 16 to 30 years, according to the quantity of antiseptic used. In a report to the International Railway Congress, in 1895, based on data from 54 railways, the average life of creosoted oak ties was placed at 25 years, of creosoted beech ties 30 years and of creosoted pine ties 20 years. A report of the German Railway Union (which includes the countries Austria-Hungary, Roumania, Netherlands, Luxemburg, Germany and Switzerland) in 1896 gives the life of treated pine ties at 20 to 23 years, beech 30 to 34 years, and oak 24 to 28 years. The life of untreated oak ties in France and Germany averages 13½ years; of untreated pine ties 7 to 8 years; and of untreated beech ties 2½ to 3 years. The Southern Ry. uses the sulphate of copper (Boucherie) treatment, injecting solution in sufficient quantity to get 0.4 lb. of the dry salt per cubic foot. On the Eastern Ry. oak ties are generally allowed to season 15 to 20 months and beech ties 6 months or longer, before treatment. The piles, which are isolated, contain 100 ties each, with 10-in. air spaces between the pieces in each layer, and the top layer is made with sawed ties laid close and sloping. To protect the ties from rail cutting use is made of creosoted poplar tie plates about the thickness of a shingle, and costing 0.8 cent each.

In Germany native oak and pine were the timbers mostly used for railway ties in times past, but owing to a decrease in the supply of these beech has come to be used on a large scale. Until comparatively recent years the zinc chloride treatment was the one most largely used. Creosoting had been practiced to a limited extent for many years, but was usually considered too expensive for economical results. For some time extensive trials had been made with beech timber for railway ties, but so far as beech treated with zinc chloride was concerned the results were not satisfactory. The objection with this method of treatment was that the preservative solution leached out, sooner or later, leaving the timber unprotected, and the additional life thereby secured was not sufficiently remunerative for the expense involved. In this way attention came to be directed to the application of creosote to beech timber, for it had been demonstrated beyond question by certain of the French railways, particularly the Eastern of France, that beech timber thoroughly impregnated with creosote becomes a durable and desirable material for railway ties. The scheme is also acceptable from the fact that a large percentage of the forest area of Germany is in beech timber, which, without some effective means of preservation, is of but little use except for fuel. The records of some of the railways of Alsace-Lorraine show in one case that 86 per cent of a lot of creosoted beech ties were in service after being 29 years under traffic.

With a view to economize in cost of materials a good deal of work is being done in Germany with the zinc-creosote process. It is the aim to reinforce zinc chloride solution with enough of creosote oil to prevent the washing out of the zinc salt, and still not use enough of the creosote material to greatly increase the expense. To the ordinary zinc chloride solution is added 5 to 8 per cent of creosote at a temperature of 149 deg. F., and the whole is thoroughly mixed together by compressed air. The extra cost due to adding the creosote amounts to about 1½ cents per tie per 2.2 lbs. of creosote injected. The amount of creosote actually injected per tie is about 4.4 lbs., and the timber takes 0.50 to 0.55 lb. of dry zinc chloride per cubic foot. The cost of impregnating a pine tie with the mixture where 4.4 lbs. of creosote is used, is about 20 cents, and about 25½ cents where 13.2 lbs. of creosote is used per tie. In Germany the expense of impregnating a tie with creosote exclusively, where 66 to 80 lbs. of creosote is used, is 50 to 59 cents.

The efficacy of this method of treatment is illustrated by statistics published by the Hungarian State railway directors, whereby it is shown that out of 9455 beech ties impregnated with chloride of zinc exclusively and laid for the purpose of a test in 1885, 81 per cent of the same had been renewed on account of decay at the end of 10 years. In another instance, of 34,175 ties so treated, 59 per cent were renewed on account of decay at the end of nine years. In another test with 25,133 ties so treated, 34 per cent were renewed after a period of seven years, and 59 per cent after a period of eight years. On the other hand, in a batch of 17,400 beech ties treated for the Prussian State railways with chloride of zinc reinforced with 4.4 lbs. of creosote per tie, there were renewed at the end of the sixth year on account of decay, 67 ties, or 0.4 per cent; 287 ties, or 1.6 per cent, at the end of the seventh year; 704 ties, or 4 per cent, at the end of the eighth year; 1450 ties, or 8.5 per cent, at the end of the ninth year, and 2280 ties, or 13 per cent, at the end of 10 years. Of 79 cubic meters of second-class beech siding ties treated at the same time, and in the same manner, only 2.6 cubic meters, or 3.3 per cent, had been renewed on account of decay at the end of 10 years. The Prussian State railways have made extensive use of this process in treating pine ties, the work being done under contract by the well-known firm of Julius Rutgers, of Berlin. The result of the treatment on pine and beech ties is a life of 15 to 18 years, and the use of zinc chloride alone has generally been given up. Following are comparisons of cost of the two processes: With the zinc chloride treatment the average cost for pine ties is 15.6 cents; for oak ties, 12 cents; for beech ties, 18.8 cents. With the zinc-creosote treatment the average cost for pine ties is 19.2 cents; for oak ties, 15.6 cents; for beech ties, 20.4 cents.

In European practice the steaming of timber for the extraction of the sap previous to the injection of creosote has been largely discontinued. Such is the case in England, where use is made of the vacuum only (Bethell process) before the creosote is let into the treating cylinder. An explanation for the English practice is that the ties, which are imported, are for the most part floated in streams after being cut in the mountains of Norway and Sweden, so that the sap becomes largely dissolved and washed out before the ties arrive at their destination. Then, after arriving in port the ties are carefully piled and permitted to season for fully eight months before they are treated so that but very little of the sap remains in the timber. In other quarters considerable objection is raised against the steaming or Blythe process. The only road in France which uses it is the "Nord." German experts claim that while steaming may serve as an effectual method of removing the sap, the condensed steam will remain in the cells to obstruct the penetration of the oil, and that it will also dilute the preservative solution to an appreciable extent. Before applying zinc-creosote, which is an aqueous solution, the timber is sometimes steamed, but even then the effect on the general result is considered doubtful. In place of steaming, where creosote is being applied, two methods of treatment are resorted to, as productive of superior results.

The first of these, and the most expensive, is that employed on the Eastern Ry. of France, namely, that of kiln-drying the timber before the creosote solution is applied. Where this method is practiced the ties are first thoroughly dried in the open air, being carefully piled for several months. The ties are then bored for the fastenings and adzed for the rail seat, and, after being run into drying ovens, are subjected to hot air at a temperature varying from 95 to 176 deg. F. for about three days. On leaving the ovens the ties are straightway conveyed to the treating cylinders, where they are subjected to a vacuum of about 26 ins., for a half hour, when the creosote is let in at a temperature of 176 F. and injected into the timber under a pressure of about 75 lbs. per sq. in., which is maintained for about an hour. This method of treatment is considered very thorough and is conceded to produce the most effective results. In some of the German plants an attempt has been made to hasten the process of kiln drying by raising the heat as high as 212 to 230 F., in order to cut down the time of application to eight or ten hours, but experience has demonstrated that such treatment subjects the timber—particularly beech—to unusual liability to checking.

The other method of treatment consists in drying out the timber in the presence of the impregnating solution. It is claimed that by this process, which was put forward by Mr. Rutgers, of Berlin, the wood need not be seasoned previously to treatment. It is placed in the treating cylinder, wherein is first produced a vacuum of 23 or 24 ins. for about 10 minutes, when the tank is filled with creosote, covering the timber, and as high as possible without reaching the pipes communicating with the air pump. The oil is then heated by steam pipes for about three hours to a temperature of 220 to 240 deg. F., and this heat is maintained about an hour longer. The effect of the heated solution is to evaporate the sap and other moisture in the timber. The theory of this action is that the temperature of the solution exceeds the boiling point of the sap. The evaporation of the sap bubbles to the surface of the hot creosote and is removed by condensing apparatus, and afterwards measured. After the sap has been expelled from the timber sufficiently the tank is then completely filled with creosote, and a pressure of about 105 lbs. per sq. in. is maintained for about a half hour, in the case of beech ties, injecting about 20 lbs. of creosote per cu. ft. or 80 lbs. per tie. More time is required by this method of treatment where the timber is not seasoned. It is claimed that by this process the ties are not so liable to check as when seasoned in drying ovens; that the sap can be extracted from the timber more thoroughly; that greater quantities of creosote can be injected into the ties than by the other treatment. The Rutgers firm guarantees an absorption of at least 24 lbs. per tie for oak ties, 79 lbs. for pine ties and 79 lbs. for beech ties, the tie being 8.85 ft. long, 6.3 ins. thick and 10¼ ins. wide. While it is assumed that this process is preferable to that of the drying-oven treatment, at least in those cases where there is not time to slowly and thoroughly season the timber, or when green timber must be employed, experience is wanting to demonstrate whether the results will be as effective.

Of all woods in Europe sound beech is the most thoroughly susceptible of impregnation. This fact is due to the circumstance that beech is mostly sap wood, and consequently all the pores, which, in their natural condition, serve to transmit water, remain permanently open; whereas, in the case of oak and pine the creosote penetrates only through the sap portion of the wood, while the heart wood absorbs but very little or not any of it. Beech wood considered most suitable for ties is furnished by trees at the age of 80 to 120 years. In France all red-hearted beech is rejected, as it is found that such timber is in most cases superannuated, and that the impregnating solution cannot be forced into the pores, which have ceased to be of use for conveying the nutritive fluids of the tree and have become closed or clogged. Results reported by certain of the French roads show that creosoted beech ties harden with age or service and eventually surpass oak ties in both durability and hardness, so that they are preferably used on lines of heavy traffic. In consideration of the foregoing qualities and the fact that the first cost of beech is less than that of oak or pine, it is therefore considered by all odds the most suitable timber for ties.

One other process which has been experimented with in Germany is the water-creosote process. This consists in injecting an emulsion of water and creosote. In European practice the strength and purity of the treating solutions are tested constantly and all stages of the processes of impregnation are watched with minute care. The use of dating nails and the keeping of careful records are generally established. Thorough seasoning before applying the antiseptic is characteristic of nearly all the work. The specifications of some of the German railways require that oak must be air-dried until it weighs not to exceed 49.8 lbs. per cu. ft., beech 45.1 lbs. per cu. ft. and pine 39.2 lbs. per cu. ft.

Notwithstanding that the zinc chloride treatment has been abandoned by nearly all, if not all, the railways of Germany, the records of some of the roads show fairly good results. In 1888 and 1889 experimental sections of track on the Bavarian State Railways, near Munich, were laid with ties of various kinds of timber, both untreated and treated with various processes, in sets of 121 ties each. In 12 years all the untreated spruce ties had been renewed twice and a few of them the third time, the average life being slightly under 5 years. In the set of spruce ties impregnated with zinc chloride none of them had been renewed at the end of 7 years, only 16 at the end of 9 years, and 43 were still in the track at the end of 12 years. The average life of kyanized spruce ties was about 9.1 years, a few of them lasting longer than 12 years. The data of the untreated beech ties are not itemized for the early years of the renewals, so that the average life cannot be computed with reasonable assurance, but nearly all had come out in 5 years, and at the end of 12 years all had been renewed twice and 106 of them the third time. In the set of beech ties impregnated with zinc chloride none was renewed until the 10th year, and 68 still remained at the end of 12 years. In some extensive experiments by the Imperial Elizabeth R. R., of Austria, the untreated beech ties were all removed in 4 years, the average life being 3.2 years. Of the beech ties impregnated with zinc chloride, 50 per cent had been renewed in 11½ years and 82 per cent in 15 years, the average life for all being about 11.4 years. The untreated spruce and fir ties were all removed in 7 years, the average life being 4.9 years, but of the spruce and fir ties treated with zinc chloride only 50 per cent had been removed in 9½ years and 73 per cent in 12 years, the probable average life for all being 9.8 years.

202. Tree Planting.—Among various proposed measures for conserving the supply of railroad tie timber tree cultivation by the railroad companies themselves has long been suggested. Between 1880 and 1890 the subject began to receive some attention on the part of railway managements, and during those years the experiment of tree planting was taken up on a few roads. On the whole the work then begun has been rather disappointing as to rate of growth. It is admitted, however, that at least some of these experiments were tried at random, without investigating the conditions most suitable for the growth of the trees, and the results are therefore not to be taken as conclusive. These failures or partial failures led to a closer study of the conditions essential to profitable growth, and eventually the business came to be better understood.

The tree generally recommended for this purpose is the catalpa, particularly the variety catalpa speciosa or "hardy catalpa," as it is commonly known. It is indigenous to the valley of the Wabash river, in Indiana and Illinois, but proven to be hardy between latitude 29 and 44 deg. north, wherever the proper conditions of soil and atmospheric moisture obtain. The utility of this timber for ties seems to be well established. Catalpa ties on the Erie R. R. and on the Cairo division of the Cleveland, Cincinnati, Chicago & St. Louis Ry. are reported to have given a service of 20 years. Under favorable conditions the tree grows quickly. Measurements of a large number of catalpa trees of known age, in Kansas, Nebraska, Iowa, Missouri, Illinois, Kentucky, Ohio, District of Columbia and Indiana, have shown an average growth of 1 in. diameter increase each year after planting. Trees six years old were found to be 6 ins. in diameter and trees 16 years old 15 ins. in diameter; trees 20 years old, from the seed, have measured 21 ins. in diameter and 50 ft. in hight. The tenor of the claims is that wherever conditions are favorable a growth of 16 to 20 years will produce trees large enough to make three to five ties. It is said that in the warm and moist climate of Louisiana the rate of growth for catalpa is almost double the above figures.

The usual scheme of planting is to set out one-year-old seedlings in regular rows, in deeply plowed ground harrowed down smooth. Until the trees grow large enough to shade the ground and keep it clear—say two to four years—the ground should be loosened occasionally by cultivation and the weeds and grass should be kept down. Young catalpa trees will not thrive well where the surrounding earth is covered with sod. The contract price for the young trees, including the work of setting them out and taking care of them two years, has in some instances been one cent per tree. A number of plantations have been set out with as few as 600 to 1000 trees per acre, but some forestry experts recommend planting them as close as 4 or 5 ft. apart each way, which requires 1750 to 2700 per acre.

The question as to the best distance for spacing the trees in planting is unsettled. The thick planters hold to the view that in early life the trees should be grown close together, so that their branches will interfere, causing a straight and tall growth of trunk, clear of limbs near the ground, and shading out grass and weeds. As the trees increase in size they begin to crowd one another and to shade off one another's branches, and about this time some of the trees will begin to fall behind. This is an indication that the ground is being overtaxed, and then the weak trees should be thinned out, in order that the others may get proper sustenance. It is expected that in six to ten years the trees will be large enough for fence posts, and then the thinning-out process should be continued to the finish, leaving only 600 to 800 of the most vigorous trees to the acre, with room to expand their limbs and thicken out their trunks. Working to this plan there will be, at the time of the final thinning down, a forest floor of decayed leaves and branches to protect the remaining trees from growth of grass from that time on. Those who favor this plan do not think that natural forest conditions can be obtained in any other way.

The thin planters claim that the trees should not be planted closer than 8 ft. apart each way (680 trees per acre) or in rows 8 ft. apart with trees 5 ft. apart in the rows, at closest, which requires about 1090 trees per acre. Their argument is that when catalpa trees are planted closer than this the roots will overcrowd the soil in a few years and stunt the growth. Then it is recommended that as soon as the trees are large enough for fence posts they should be thinned out to 16x16 ft. (170 trees per acre) or 10x16 ft. or 8x16 ft. (270 to 340 trees per acre), at most, for the trees intended for tie timber. To keep down the grass when setting the trees thinly it is considered good practice to plant corn or some other subsidiary crop between the rows of trees, for a season or two. Whatever is planted should be in rows, so that the trees may get the benefit of cultivation. To enforce a straight and tall growth with small trees that stand so far apart they are cut back and pruned. After two or three years of growth from the time of transplanting, the tree is cut off at the ground and allowed to sprout for one season. The next season all the sprouts are cut away except the most vigorous one, and that is allowed to remain to form the final tree. These sprouts from the old root shoot up amazingly tall and straight the first season, and in about four years from the time of cutting back they will make post timber. Cultivation must be continued until the trees shade the ground effectively.

The tendency late years seems to be toward thin planting, or to the extent of about 1000 trees per acre, reducing the number by thinning to about 500 trees in the period from the eighth to the twelfth year from planting. By whatever plan the trees are planted they should be systematically pruned, cutting the lower branches off close to the trunk. The first general pruning is usually done when the trees are five or six years old, and by the tenth year they need it again, but dead limbs and a tendency to fork near the ground should be attended to promptly, as soon as conditions require. The fallen branches should be allowed to lie and decay on the ground, as they assist in forming the humus of a forest floor.

It has long been a favorite idea with many persons who have given attention to timber culture that the spare land on railroad right of way might be utilized to grow catalpa trees. It has been figured that trees could be grown thickly enough along the right of way to fully supply all requirements for fence posts, telegraph poles and ties for the adjoining track as such supplies would be needed. The practicability of such a scheme has not, however, been demonstrated, and so far as there has been any experience in this direction the results have been disappointing. The weight of expert opinion and of experience seems to be that the width of available right of way on each side of a railroad track is not sufficient for the maintenance of forest conditions. During the year 1883 the Pennsylvania Lines West set out 86,000 catalpa trees along both sides of the track, on the right of way. Some of these were planted on the line between Richmond, Ind., and Indianapolis, and others between Richmond and Logansport, Ind. After 19 years some of these trees had attained a diameter of 12 ins., but generally not exceeding 8 ins., and not enough of them worth speaking about were of a size or shape that would make track ties, and only about 40 per cent of them were suitable for fence posts. The experience was that the branches grew very rapidly, and much labor was required in trimming, to keep them clear of the telegraph wires, but the increase in size of trunk was slow. But, after all, it is not a question of great importance whether or not the right of way can be utilized for timber cultivation. What railroad companies are most concerned about is whether durable ties can be grown in a reasonably short time, and at moderate cost, compared with past prices, or say 40 to 50 cents apiece. If such can be done there would seem to be but little question as to the proposition of maintaining the supply of timber for track purposes indefinitely, for if such were once demonstrated to be practicable farmers would undoubtedly go into the business.

Experience shows that a satisfactory growth of catalpa requires at least a moderate amount of moisture in climate or soil. About the year 1880 the Southern Pacific Co. planted catalpa trees quite broadly over the State of California, and after 20 years of growth the average diameter of the best specimens was only 4 ins. The best growth was where there was most moisture. In dry places the plants did not grow into trees at all. In 1882 the Kansas City, Ft. Scott & Memphis R. R. and other parties finished planting a portion of two square miles of land in eastern Kansas with catalpa trees 4x4 ft. apart. At the age of 10 years about one fourth of the trees were cut and allowed to lie on the ground, not being of any value. During the next 10 years 500 to 600 posts per acre were obtained by the thinning process, some acres yielding 1200 to 1500 posts. During the 18th and 19th years 120,000 posts were taken off and some pole timber 26 ft. long, with a tip diameter of 6 ins., was obtained. After

20 years the trees had been thinned to about 1800 per acre, and some of them had attained a diameter of 12 to 20 ins. and a hight of 40 to 45 ft. The diameter of some of them, however, was only about 6 ins., the largest trees being found on the best soil. It was observed that on parts of these tracts where corn had not grown well in previous years the trees did not thrive. It is a point emphasized by authorities on forestry that land for satisfactory growth of catalpa should have a porous subsoil and be able to produce good corn or wheat. The whole cost of the land, the trees, the planting, the cultivation, the interest on the capital and the general attention for 15 years was about $100 per acre. The following information regarding this plantation was kindly supplied in July, 1902, by Mr. Geo. E. Kessler, superintendent of parks for the Frisco System:

"The catalpa plantations along the former Kansas City, Fort Scott & Memphis R. R., now part of the Frisco System, are on the prairie lands about 17 miles south of Fort Scott, on the Joplin division. The property belonging to the railroad company, at Farlington, Kan., contains 640 acres, of which about 400 acres are in catalpa trees, the remaining lands in some miscellaneous and practically valueless plantation, but largely in grassy swails. The other property, containing 800 acres and belonging to Mr. H. H. Hunnewell, of Boston, lies about 4 miles southwest of Farlington, and of this something less than 500 acres are planted in catalpa trees. The planting of both properties was done between the years 1879 and 1882. Except for a small portion of the work done in 1879, the rest was planted afterward by Messrs. Robert Douglas & Sons, nurserymen of Waukegan, Ill. The trees were planted in rows 4 ft. apart and 4 ft. apart in the rows, and were cultivated for a few years until they shaded the ground, and then allowed to grow undisturbed. About ten years ago the first thinning was made, taking out about one fourth at that time, and since then a very large amount of thinning has been done. The first cutting was valueless, but the next time a small number of posts were cut, and in recent years the entire cutting has been utilized for fence posts, largely by the railroad company for its right of way fences.

"The trees now stand about 45 ft. high, at maximum, but along the edges of the bad lands some of them are not over 10 ft. high; generally, however, about 40 or 45 ft. high, and in diameter about one third are from 12 to 20 ins. at the bottom, the remainder being from 6 to 10 ins. During the past 5 or 6 years the trees have made very slow growth, and have to some extent suffered from a fungus growth in the heart, as a result of the dead branches remaining on the trees, the fungus entering at the points of juncture with the trunk. The past 5 years have, however, been exceedingly dry ones in that region, and trees standing out alone have suffered just as much and show the same conditions of lack of growth, as well as the fungus effects, as those within the plantation, planted as closely as they were. We are cutting a large number of trees in the course of systematic thinning and these will develop fence posts only. The trees have barely reached the size sufficient to make poles for telephone lines, and are certainly very far from supplying ties. Both of these plantations are on very thin prairie soil underlaid with gumbo, and this, together with the dry seasons, has not given the plantation the vigorous condition it should have at this time."

Previous to setting out this plantation the company had experimented with a 100-acre tract near Farlington, Kan., planted with the following varieties of trees: White ash, black walnut, wild cherry, osage orange, ailanthus, catalpa bignonioides and catalpa speciosa. After carefully noting the annual growth and general appearance of the trees for some years the decision as to best progress was in favor of the catalpa speciosa. It not only proved to be the strongest grower, but was also the most tenacious, standing dry weather better than any other species. The catalpa bignonioides, also called catalpa catalpa, is of small growth, crooked and seldom forms a well-shaped tree. It is native to the southeastern states. The speciosa has heart-shaped leaves. The flowers are 2 ins. long, nearly white but faintly spotted, the lower lobe being notched. The seed pods are thick, 12 to 14 ins. long and ¾ in. in diameter. The flowers of the bignonioides are smaller than those of the speciosa and bloom two weeks later. They are much spotted with yellow and purple and the lower lobe is entire. The pods are thin, and of less diameter and shorter than those of the speciosa. The bark is scaly, peeling off in strips like that of wild cherry; many of the leaves are three pointed. The seed is plentiful and easily gathered, while that of the speciosa is scarce on the tree, hard to collect and comparatively expensive. The speciosa has deeply furrowed bark, like the ash, and it does not peel off in scales.

The fact that there are two varieties of catalpa native to this country is important to bear in mind, for the bignonioides is worthless for timber, and there are many hybrids, all of which are inferior to the speciosa. For a long time it was not generally known that two varieties of catalpa existed in the United States, it being supposed that the smaller tree of the Carolinas and southeastern states was due to less favorable conditions of climate and soil. The discovery was made in 1853, by Dr. John A. Warder, of Dayton, Ohio (hence the botanical name "catalpa speciosa, Warder"), but only an informal announcement was made at the time. It seems that it was not until 1880 or 1881 that the distinction was made known to science in a formal manner, and it was some years later before it came to be generally understood. This explains why so many experiments with catalpa in this country have been unsuccessful, and in this connection the following incident in the history of railway tree planting is in point.

One of the earliest railways to commence tree planting for growing post and tie timbers was the St. Louis, Iron Mountain & Southern. During the '60's this road planted 50,000 catalpa trees on the right of way near Charleston, Mo., and a farm of 100,000 trees on the Belmont branch, 18 miles from Belmont, Mo. These trees were all raised from the seed. In 1880 a farm of 150,000 trees was set out at Bertrand, Mo., making, altogether, about 200 acres of catalpa trees. Some seed of the catalpa kempferi (another variety inferior to the speciosa), imported from Japan, had been planted along with the rest. Some years later large seed firms began to collect seed from one of these plantations, and thousands of pounds were distributed to all parts of the country. Eventually the distinction between the two American varieties came to be generally known, and then it was discovered that not one of the trees of this plantation was catalpa speciosa: it had grown up with the bignonioides and kempferi varieties and hybrids of the same, and in course of time most of the trees were cut down as worthless.

On the profitableness of tree planting the division of forestry of the United States Department of Agriculture has issued a publication treating of the limitations of catalpa growth as affected by the soil, moisture, etc., and examples are cited in some detail which show the results of experiments in this field. In 1890 Mr. L. W. Yaggy started a plantation of 440 acres of catalpa trees in the valley of the Arkansas river, near Hutchinson, Kan., where the natural conditions were favorable and well adapted to tree growth (sandy soil subirrigated from natural sources). The trees were set, 3½x6 ft. apart, and the farm produced, after eight years of growth, fence posts, 4 to 6 ins. in butt diameter. This time included two years of growth from which the trees were cut back to the ground in order to produce a straighter growth. From figures prepared by government experts who investigated the products of this farm it appears that the gross value of the marketable timber crop produced in ten years was $267.15 per acre. The total cost of growing and marketing the timber was $51.70 per acre, and allowing 6 per cent compound interest on all expenditures incurred from the time of planting, including the purchase price of the land, $25 per acre, the total expense per acre was found to be $69.60, leaving a net profit of $197.55 per acre. The only other of these early plantations, not already mentioned, which seems to have been commercially successful is the farm of Mr. Geo. W. Tincher, near Wilsey, Morris Co., Kan., on high prairie upland. It was started by planting 31 acres in 1885, with trees 4x4 ft. apart. After 17 years this plantation was thinned out one half by removing every other row. At that time some sections of the forest were able to furnish 2000 fence posts to the acre, but "not a single tie." The trees averaged an annual increase in diameter of 1-3 to ½ inch. The owner concluded that the trees in this part of the farm were set too close, and in 1899 nine acres were planted with trees 5x7½ ft. apart, and in 1900 twenty acres with trees 5x14 ft. apart, which give promise of better growth.

From the foregoing it appears that more than 30 years of experimenting with forest cultivation has failed to produce tie timber. Experience, has, however, shown some bad mistakes and no small deficiency in knowledge of timber cultivation in general, and the results are not by any means considered final. About the year 1900 the question was revived, and the result was that a number of railroads started catalpa plantations for the purpose of growing tie timber. In 1899 the Cleveland, Cincinnati, Chicago & St. Louis Ry. set out 30 acres of land with some 30,000 catalpa trees. At Brightwood, Ind., this company has a farm of 20 acres, 1000 trees to the acre, planted in 1900. Besides these it has other small tracts planted with catalpa. In April, 1901, the Rio Grande Western Ry. planted a nursery of 60,000 catalpa trees on irrigated land near Provo, Utah. The trees made a strong, healthy growth of 6 to 8 ft. during that season and the next year were transplanted at points along the line of the road. In the year 1902 the Boston & Maine R. R. planted 10,0.0 catalpa trees on waste land, outside of location, in the Merrimac river and Shawsheen river valleys, 20 to 30 miles from Boston. The trees were set 8 ft. apart each way, with the intention of thinning to 16 ft. apart when large enough to make fence posts. During the spring of 1903 this company set out a plantation of 6,000 chestnut seedlings near North Wilmington, Mass. Chestnut is a rapidly-growing tree that is hardy in all of southern New England and is found abundantly in the middle Atlantic states. It will grow on a great variety of soils, and as it makes excellent ties the experiment of this company should be watched with interest. During the year 1902 the West Virginia Central & Pittsburg Ry. set out 5900 catalpa trees, 3500 near Kerens, W. Va., and the remainder near Shaw, W. Va.

The Illinois Central R. R. has two catalpa plantations set out in 1902: one of 225 acres, at Harahan, La., near New Orleans, and a smaller tract at Tucker, Ill., planted with 20,500 trees. In the scheme of planting, seedling trees were set 8 ft. apart, with the intention of thinning them out when sufficiently grown to make fence posts. At the Harahan farm cultivation during the early years was provided for by allowing market gardeners to work the land between the rows of trees, without charge for rent, upon the condition that the weeds should be kept down and no injury done to the trees. At the Louisiana State Experiment Station, which directly adjoins this tract, catalpa trees have grown at the rate of 2 ins. increase of trunk diameter per year. Near Newton Hamilton, Pa., the Pennsylvania R. R. has a grove of 15,000 yellow locust trees planted in 1902, and at Conewago, Pa., 43,000 of these trees were set out in 1903. The trees were set out 10 ft. apart. It is estimated that a growth of 15 years will be required to make tie timber. The Michigan Central R. R., during the years 1900-02, planted some 34,000 catalpa trees at various points along the Canadian division. Some experimental planting has also been done by this company at Glenwood, Mich.

203. Metal Ties in Foreign Countries.—As elsewhere stated in this volume, the results of extensive and long-time experiments with metal ties are not to be found in the United States. In many of the foreign countries, however, the use of metal ties is beyond the experimental stage, and the mileage of track laid with such ties is increasing. In countries where suitable timber is scarce and costly the use of metal ties has been found economical, and in some parts of Asia and Africa the destructive work of white ants on wood ties practically compels the use of some form of metal track support. About 1889 the Forestry Division of the United States Department of Agriculture went into the subject of metal railroad ties very thoroughly, inquiring into the extent to which such ties were used in all the countries of the world, the practical experience in the use of such ties, and data were collected on their durability, efficiency, the economy in their use, methods of manufacture, etc. These investigations were made by Mr. E. E. R. Tratman, by direct inquiry of official sources, and the results were published in detail in Bulletin No. 4 of the Forestry Division, issued in 1890. Again in 1894 the matter was taken up and thoroughly investigated by Mr. Tratman, mainly for the purpose of ascertaining the progress and experience in the use of metal ties and longitudinals subsequently to the previous investigation. The results of this investigation were published at length in Bulletin No. 9 of the Forestry Division, as supplementary to Bulletin No. 4. The report of 1890 shows that 24,802 miles of track was laid with metal ties and longitudinals, or 13.2 per cent of the mileage of the entire world at that time, excluding the United States and Canada. The report of 1894 shows that the length of track laid with metal ties and longitudinals had increased to 34,978 miles, or 17.2 per cent of the entire mileage of the world at that time, outside of the United States and Canada. By continents the mileage of metal track in 1894 was divided up as follows: Europe, 13,404 miles (longitudinals 3645 miles, plates 257 miles, cross ties 9502 miles), out of a total of 137,000 miles of track; Asia, 14,586 miles, out of a total of 22,000 miles of track; Africa, 2326 miles, out of a total of 5675 miles of track; Australia, 234 miles, out of a total of 12,000 miles of track; South America, Central America, West Indies and Mexico, 4416 miles, in a total of 21,500 miles of track. The general summary in 1894 stood as follows: Metal longitudinals 3645 miles; metal bowls and plates, 12,375 miles; metal ties proper, 18,958 miles. It is known that since 1894 the mileage of all-metal track in foreign countries has been increasing, but since a general summary of subsequent date has not been made, the data of the total mileage at the present time are not available.

The countries that were using all-metal track most extensively in 1894 were Germany, with 11,605 miles, including 3580 miles of track laid with metal longitudinals; British India, with 13,655 miles, including 7595 miles of track laid with bowls and plates; and the Argentine Republic, with 3638 miles, including 3438 miles of track laid with bowls and plates. Ten other countries had between 200 and 900 miles of track laid with metal ties and six more had between 100 and 200 miles so laid. In nearly all of these countries the mileage of track laid with metal ties had materially increased between the years 1890 and 1894. On 54,742 miles of line of the German Railroad Union, in Germany, Holland, Austria, Hungary and Roumania, in 1897, 15,774 miles of track was laid with metal supports, of which 2095 miles was metal longitudinals. This was an increase of about 3600 miles of all-metal track over the mileage so laid in 1894, but the mileage of track supported on metal longitudinals had decreased 1547 miles.

Metal Longitudinals.—In 1894 the use of metal longitudinals was confined to two countries, namely, Germany and Austro-Hungary. A common type in use is an inverted flanged trough, placed longitudinally under each rail and held to gage transversely by tie bars. The Haarmann compound "self-bearing" girder rail, 8 ins. in hight and 12 ins. wide at the base, is laid upon the ballast without intermediate supports, and is held to gage with tie bars. The rail is rolled in two halves, separable through the middle vertical plane of the web, and to hold the two halves in their proper relative positions a tongue and groove are provided along the middle line of the surfaces in contact. The halves are put together to break joints and are held with bolts 12 ins. apart, on a line just under the head. The joints are spliced with long angle bars. The bottom or base is held together by small transverse channel-iron clamps bolted to the under side. The edges of the base or flange have depending ribs or beads, and the rail weighs 116 lbs. per yd. In laying the rail it is buried to the head in ballast. The Haarmann-Vietor rail is another that is laid on the "self-bearing" plan. It is 8 ins. high and 8 ins. wide on the base and weighs 127 lbs. per yd. The rail is rolled with an unsymmetrical head, or with the "web aside" with respect to the head, so that the webs may lap at the joints. The lap joint, which is 10 ins. long, is made by scarfing the head and base of each rail, on line with the side of the web, so that no part of the web is removed. The splices are 6-bolt angle bars 29¼ ins. long.

The expense of maintaining track surface with longitudinal supports is excessive and it is also difficult to detect defects in the ballast support, unless it is watched while a train is passing, as the combined stiffness of the rail and sleeper frequently causes the track to spring to even surface as soon as the load passes. It is also difficult to obtain proper drainage, particularly on grades, where the water tends to follow the lines of the rails. At frogs and switches the construction is complicated. The roads which have experimented with metal longitudinals to greatest extent are the Alsace-Lorraine, Bavarian State, and Prussian State railways. The report of 1894 showed that the use of longitudinal supports was being gradually abandoned, as was also the case with bowls and plates, which were in service mainly in tropical countries. In the evolution of railroads it seems to have become quite definitely settled that the cross-tie system is destined to remain the leading, if it does not become the exclusive, system in use.

Metal Cross Ties.—Generally considered, the predominating type of metal tie in use in foreign countries is of inverted trough section, with closed ends, designed on the principle of the Vautherin tie, invented by a French engineer of that name and first used on the Paris, Lyons & Mediterranean Ry., in 1864. (The first metal cross ties were used in 1860, by Mr. Le Crenier. The form of tie was U-shaped in section, 7 ft. 10 ins. long, 10 ins. wide, weighed 52 lbs. and was laid under T-rails) The original Vautherin tie was sectionally an inverted trough, with flaring sides, having a rib or narrow horizontal flange on each lower edge. In 1894, 104 miles of the State Railways of France were laid with Vautherin ties of uniform section, first put down in 1887. These ties are 8.2 ft. long, about 10 ins. wide over all, with a top width of 4.8 ins., and the average weight is about 125 lbs. In 1901 this railway system had 600,000 metal ties in the track.

The Post Steel Tie.—The Post steel tie is very well known in foreign countries and is quite extensively used in most of the countries of Europe, in the

East Indies, South Africa and the Argentine Republic, 1,500,000 of these ties having been in service since 1894. This tie, which was designed by Mr. J. W. Post, divisional chief engineer with the Netherlands State Railways, is shown at the right, in Fig. 485. It is of rolled steel, with closed ends, and has a thickened rail seat with an inclination of 1 in 20. The standard tie of this design is 8.36 ft. long. The tie is of "variable profile." The cross section at the rail seat is polygonal, 4.4 ins. wide on top, 10.2 ins. wide across the bottom and about 3 ins. deep. The cross section at the middle is an inverted V, 4.38 ins. deep, with a top radius of 1 in. and a bottom width of 5.4 ins. The sides of the tie are about ¼ in. thick at the lower part and ⅜ in. thick at the upper part. The thickness of the top table varies from .52 in. at the rail seat to .24 in. at the middle. The intention of deepening and narrowing the section of the tie at the middle is to give transverse strength and to decrease the bearing area where it is not needed, thus decreasing the tendency to center-binding. The fastenings consist of bolts and clips. The weight of the tie of these dimensions is 118 lbs., but as used on some roads it is made considerably heavier.

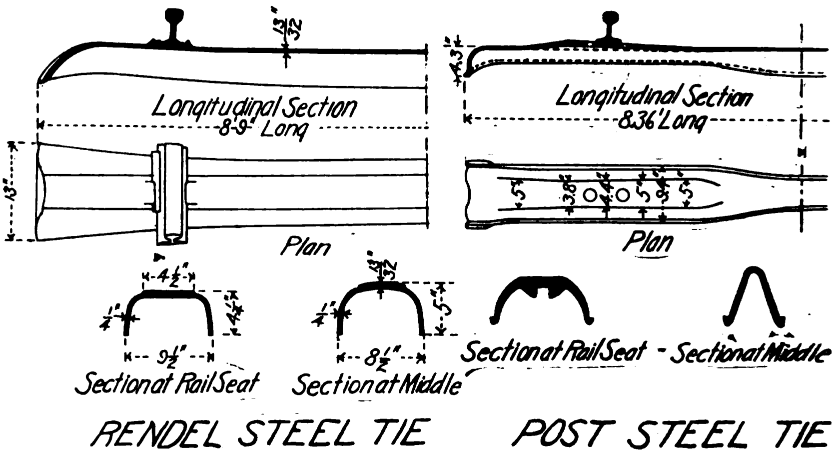


Fig. 485.—Types of Steel Ties Used in Foreign Countries.

The Post tie as used on the Liege & Limburg division of the Netherlands State railways, in Belgium, takes two forms respecting the middle portion, one being belly-shaped, as shown in the figure, and the other straight on the bottom and humpbacked on top, and known as the "dromedary" type. According to official reports the latter form gives the better satisfaction, as the middle portion of the tie is not bedded in the lower and firmer portions of the ballast, and therefore not so liable to center-bind the track. On this road metal ties have been in use since 1865. In an official report of the road published in the Bulletin of the International Railway Congress for July, 1898, an account is given of the experience had with steel ties on 27 trial sections, during the preceding 17 years. The trial sections were all single track, ballasted with slag, sand or gravel, and laid with rails weighing 76 lbs. per yard, ties 3 ft. apart centers. The heaviest engine weighed 68 tons, with a maximum axle load of 13.9 tons; the traffic over the lines was from 14 to 29 trains per day, the highest speed 47 miles per hour, and the ultimate traffic 100,000 to 150,000 trains. The steel tie most favorably reported upon was of the Post pattern, first laid in 1884, and the conclusion was that the life of a steel tie equals several times that of an oak tie. Cracks and breaks in steel ties noticed in the beginning were due to the fact that the holes for the fastenings were punched. When these holes were drilled the evil disappeared. A plate between rail and tie increased the durability of the latter. It was also found that with steel ties of the Post design there was less danger of the rails spreading than with oak ties. Some exceptions are cited where preference should be given to oak ties, such as on badly drained lines, on new track that has not fully settled, on swampy ground, and on clay or other ballast which has a high tendency to retain water. In 1901 the St. Gothard Ry. of Switzerland had in use 400,000 iron and steel ties (about 70 per cent of all ties), the most approved type being the Post steel tie. As there made the tie was 8 ft. 10 ins. long, 15-32 in. thick and weighed 163 lbs. The maximum locomotive axle load was 15½ tons and the maximum speed 53 miles per hour. On the German railways which use steel ties the maximum locomotive wheel load is 8 tons.

The Rendel Steel Tie.—Another familiar design of steel tie is the Rendel pattern, shown at the left in Fig. 485. It is in extensive use in India (where it is known as the "peapod sleeper") and in Mexico. As made for the Indian State railways it is 8 ft. 9 ins. long (gage 5½ ft.) and weighs, exclusive of fastenings, 120 lbs. The tie is stamped from a steel plate ¼ in. thick on the sides and 13-32 in. thick at the middle portion, which forms the top table, uniformly 4½ ins. wide. At the rail seat the depth is 4¼ ins. and the bottom width 9½ ins.: at the middle the bottom width is 8½ ins. and the depth 5 ins. The fastenings consist of two lugs stamped up out of the top table, for each rail, and a flat tapering key, which is driven between the outer lug and the rail flange. As made for the Mexican Ry. the ties are 8 ft. 3 ins. long and weigh 124 lbs., exclusive of fastenings. In 1900 this road had 287¼ miles of track (including all of the main line) laid with steel ties. With the ties in use on this road a key fastening is used, but the lugs punched out of the tie are reinforced by a small rib. This road is standard gage and the locomotives in use are of Rogers, Brooks and Baldwin make, of good weight. There are also in use a number of Fairlie double-ended bogie mountain engines, weighing 100 tons each, all the weight being carried on the drivers. Each of these engines has two boilers which rest upon two trucks having three pairs of drivers each, or twelve wheels in all. The ballast in use is a kind of volcanic substance called "tisontli." This material is porous, rather light and not hard, and is said to answer the purpose of ballast excellently.

The Mexican Southern Ry. has 139 miles of track laid with Rendel steel ties, the oldest of which were put down in 1891, and after 11 years of use no appreciable corrosion could be detected except in alkali soils. The ties laid on most of the line are of the design illustrated in Fig. 486. They are of pressed steel, 5 ft. 5 ins. long, the gage of the track being 3 ft. and the weight of the rail 50 lbs. per yard. The top of the tie is not exactly straight, the middle portion being depressed 9-16 in. below the ends, which gives the rail an inward cant of 1 in 24. The weight of the tie is 64 lbs. The rail fastening consists of two lugs 3 ins. wide, struck up out of the top table, and a tapering key 6 ins. long, 1⅛ in. wide and ⅝ in. thick at the larger end, and ⅞ in. wide and ½ in. thick at the smaller end, as shown by the plan and sectional drawings. The small end of the key is split, so that it may be opened out and resist any tendency to work loose. In laying track to gage, the key is driven under the lug on the outside of the rail, but in widening the gage on curves the adjustment is effected by changing the key from the outside to the inside of the rail. Experience with this tie has shown that it is weakest at the rail seat, owing to the large amount of metal stamped out of the top table to form the lugs, and to correct this evil a new tie was designed in 1899, with an improved fastening. This tie, shown as Fig. 487, is 6 ft. long and 5 ins. deep at both the ends and the middle. The width of the tie at the end is 13 ins., the width across the bottom at the middle, 8½ ins., and the width of the top table 4½ ins. The weight of the tie is 84 lbs. The rail fastening consists of a U-bolt, passed up through the tie from underneath, and clips. These clips are reversible, but unsymmetrical with respect to the bolt passing through the same, so that by turning the clips over, an adjustment of the gage may be effected, thus providing for widening the gage on curves. On this road steel ties are not used on bridges, in switch leads or in and around shops or roundhouses. Experience has shown that around such buildings metal ties corrode very rapidly. Before laying the ties it is the practice to coat them heavily with coal tar, to prevent oxidation. On curves the ties are spaced at 2-ft. centers and on tangent a little farther apart.

Concerning the advantages and disadvantages in the use of steel ties, as learned from experience with the same on this road, the following are some of the points observed. It is found that a longer time is required to obtain good alignment and surface than is the case on track laid with wooden ties. Against the steel tie there is the disadvantage of increased first cost. On the other hand the steel tie is considered safer than the wooden tie, especially on curves, as no rail braces or tie plates are required, and spreading of the gage or tilting of the rails is impossible. It has been found that with steel ties there is a reduction in the cost of maintenance of fully 50 per cent, compared with track laid with wooden ties. The ties are of uniform size, and, so far as this matter is of any importance, they afford uniform support to the rails. Line and surface are better preserved, and there is a reduced cost of handling and laying track, as compared with wooden ties; and there is said to be less noise in the running of the trains. The ties cannot be burned and the damage to track in case of derailment is less than occurs with derailments on wooden ties.

The most suitable ballast for steel ties, as ascertained through experience with the same on this road, has been found to be gravel or very coarse sand. Broken rock or slag, especially when broken as coarsely as it usually is for track laid with wooden ties, does not give satisfaction. In fact, the difference between the relative merits of gravel or sand, and broken rock, as a ballast for track laid with steel ties is regarded by the officials of this road as amounting to the difference between success and failure in the use of such ties. The ballast is filled in to cover the tops of the ties, and to keep down the dust in the dry districts the track and shoulders are covered with a layer of broken stone about 2 ins. deep. The heaviest engines in use on this road are eight-wheel English engines weighing 56,000 lbs., one class of ten-wheel English engine weighing 68,000 lbs., another class of ten-wheel English engine weighing 76,000 lbs., and Baldwin consolidation locomotives weighing 88,000 lbs. The engines of the latter class have 14,000 lbs. on each of the rear driving wheels. These engines pull net train loads of 120 tons up 4 per cent grades on a very crooked mountain division 40 miles long. In this distance the road rises through an elevation of 4300 ft. The maximum grades are 4 per cent, compensated on curves sharper than 9 deg. Many of the curves are as sharp as 17½ deg. It is claimed that the steel tie has nearly every advantage over oak ties on these steep grades.

Since both oak and steel ties have been used on this road under the same conditions of climate, soil and traffic, there has been good opportunity to observe the relative merits of each. The following interesting statement of the cost of track maintenance with the two kinds of ties was prepared by Mr. T. A. Corry, resident engineer of the road. The oak ties referred to were 6½ ft. long, 8 ins. wide and 7 ins. thick.

Mexican Southern Ry., Ltd., Puebla, Mexico, Jan. 8, 1900.

Comparison of Maintenance Expenses—Steel with Oak Ties.

1 kilometer=1000 meters=3280.87 ft.

No.	Items.	Track with Steel Ties.	Track with Oak Ties.
1.	Number of kilometers of track (main line)	223.9	143.1
2.	Number of ties per kilometer (1300 to 1600) average	1400	1400
3.	Estimated duration of ties in years not less than	30	5
4.	Original cost (1891) in Mexican currency	$1.42	$0.62
5.	Original cost (1891) per kilometer	$1988	$868
6.	Annual renewals per kilometer	*46 2-3	280
7.	Annual renewals cost per kilometer	$65.27	$173.60
8.	Daily renewals per section (approximate)	2.4	10.7
9.	Lengths of sections—kilometers	16	12
10.	Number of foremen per section, daily	1	1
11.	Number of laborers per section, daily	3	5
12.	Cost of foremen per section, daily	$1.50	$1.50
13.	Cost of laborers per section, daily	$1.50	$2.50
14.	Total wages per section, daily	$3.00	$4.00
15.	Total wages per day per kilometer—cents	18.75	33.33
16.	Cost of tie renewals per day per kilometer—cents	17.06	47.56
17.	Total wages and tie renewals per day per kilometer—cents	35.81	80.89
	Saving in favor of steel ties=55.73 per cent.		
	Supposing oak ties to last 6 years instead of 5, and price of steel ties to be $3 each, then item No. 16 would be, in cents	38.36	39.63
	And item No. 17 would be, in cents	57.11	72.96
	Saving in favor of steel ties=21.72 per cent.		

*None has been removed since first put in (1891).

N. B.—(1) The assumed life of steel ties (viz., 30 years) is evidently too short.

(2) The original cost of steel ties in 1891 was $1.42 each, delivered at Puebla. The Mexican silver dollar was then worth 38 pence—or about 79 cents

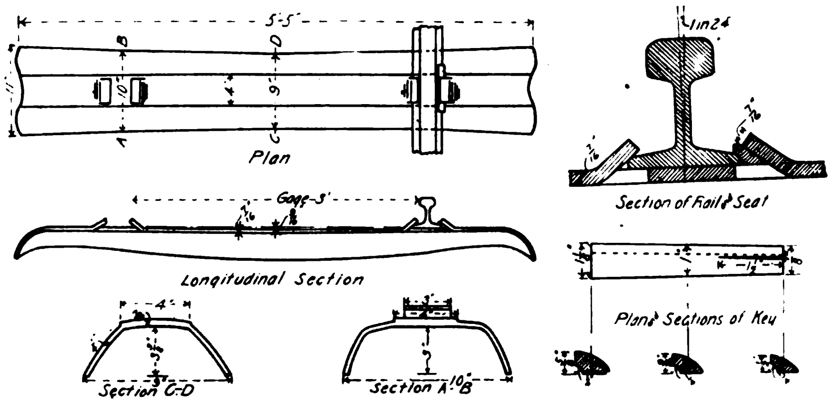


Fig. 486.—Rendel Steel Tie, Mexican Southern Ry.

U. S. currency. The Mexican silver dollar is now worth about 23⅜ pence, or say 47 cents U. S. currency.

(3) Original cost of oak ties (in 1891) was actually 95 cents each, Mexican silver. Same tie can be bought now for 62 cents, but the price is getting higher.

It will be noticed in this statement that the expense for labor reported for maintaining track laid with steel ties is very much less than that employed in connection with the oak ties. The length of sections where the steel ties are used is about ten miles, whereas the sections on track laid with oak ties are about 7½ miles long. The working force on the 10-mile sections, laid with steel ties, is a foreman and three men, while on the 7½-mile sections, laid with oak ties, it is a foreman and five men, or 50 per cent larger for a section of track only three fourths as long. It is the disparity in the amount of labor actually employed on the two kinds of track and the high cost of new oak ties for renewals which overbalance the additional investment required by the first cost of the steel ties, which, at the time these ties were laid, was about 130 per cent greater than the cost of oak ties. Taking interest charges (say 4 per cent) into account, there is still a saving of 40 per cent in favor of the steel tie. Mr. Corry then compares the cost of maintenance with the two ties on an assumed price of $3 for each steel tie, which was the price of these ties unloaded from the ship at Vera Cruz at the time he prepared his statement, there being, just about that time, a remarkable advance in the price of steel. Even at this high price there is a saving of current expenses in favor of the steel ties, but figuring interest charges at 4 per cent there is a showing of about 21 cents per kilometer per day in favor of the oak ties, which illustrates the advantage of buying metal ties when the price of steel is down. Mr. Corry states it as his belief that if steel ties laid in a wet climate are coated with coal tar once in about every 10 years, or ties laid in dry climate once every 15 or 20 years, they will last indefinitely, so far as the matter of corrosion is concerned.

In 1900 the Interoceanic Ry. of Mexico, the gage of which is 3 ft., had 163 miles of track laid with Rendel steel ties weighing 90 lbs. each. The design

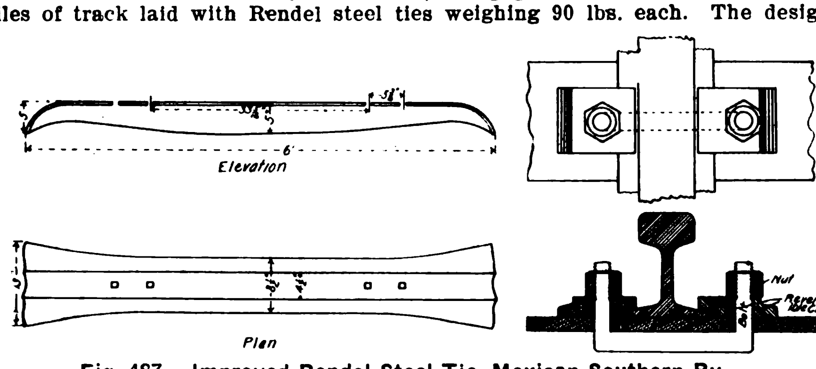


Fig. 487.—Improved Rendel Steel Tie, Mexican Southern Ry.

is similar to that of the Mexican Southern ties, and the experience extends back to about 1890. After being in service 10 years there were no visible signs of deterioration. The total life is estimated by the officials of the road to be at least 30 years. Regarding the question of economy Mr. W. T. Ingram, chief engineer, has stated as follows: "Unquestionably they are a great boon to us, with very heavy grades and curvature and a rail weighing only 40 lbs. to the yard—in fact there are portions of the road running through a zone of an almost perpetual rainy season, which could only be maintained at very great expense, were it not for the steel ties. The cost of maintenance is also an item of considerable importance, since the steel tie once laid and bedded on almost any kind of ballast, except coarse rock, keeps the track in good line and surface with but very little attention. Of course, their first cost is heavy, but unquestionably they are highly economical from all points of view." In 1898 the Interoceanic Ry. purchased 90,000 of these ties, costing £6, English money, per ton at Glasgow, the sea freight and charges bringing the price up to $2.32½, Mexican money, per tie, at the ship's side at Vera Cruz. During the succeeding year, however, the price gradually advanced until it was £7½ per ton at Glasgow, or about $3 Mexican money, per tie, at Vera Cruz. It thus appears that, after all, the "rapidly vanishing" wooden tie is a much steadier article in price than the metal tie.

The Boyenval-Ponsard steel tie is of corrugated shape, the section being that of three united parallel troughs, the middle trough open at the top, the two outer ones open at the bottom and closed at the ends with riveted angle pieces. The size is 8.2 ft. long, 8 ins. wide on top, 10.2 ins. wide across the bottom and 2.8 ins. deep. The upper face is made up of two bearing surfaces each 2.4 ins. wide, with a channel 3.2 ins. wide between them. The outer channels have flanges 0.7 in. wide. The thickness of top and bottom is .32 in., of the sides .20 in., and the weight is 130 lbs. In 1894 this tie was used on 375 miles of railway, in a number of countries, including France, Algeria, Egypt, Argentine Republic and Brazil.

The Webb Steel Tie.—The metal tie that has been used most extensively in England has been the Webb pattern, which in 1890 was in use on about 56 miles of track. These ties are of inverted trough section and straight, with open ends, flaring sides and small flanges on the bottom edges. They are of rolled steel 5-16 in. thick and 9 ft. long. The top width is 6 ins. and the bottom width 11 ins., the depth 2½ ins. and the weight, exclusive of fastenings, 136 lbs. The fastenings consist of chairs, for the double-headed rails, the chair being in three parts (a base plate and two jaws) riveted to the tie. The rail is secured by a wooden wedge driven in between the rail and the outside jaw of the chair. These ties are in use on the London & Northwestern Ry., where 1738 were laid as early as 1880 and enough to lay 9 miles of track were put down between that year and 1883, when 15,882 were in service. At the beginning of the year 1900, 13,418 of these ties had been taken up, 10,479 being scrapped and 2939 relaid in sidings. Of those scrapped 7454 were cracked or broken, 2481 had either loose rivets or broken or loose chair jaws, and 544 had failed by corrosion. The age of the ties taken up was 1 to 19 years, and the average age 8 years. Out of 100,000 steel ties laid on this road between 1880 and 1890, 54,000 had been scrapped or relaid in sidings, and 46,000 were still in main-track service, in the early part of 1900. No steel ties were laid after 1890. The officials are not in favor of extending the use of steel ties. Those in use are rather light for the service, and if any more were used a heavier pattern would have to be adopted. The first cost of the steel ties is more than that of creosoted pine ties, and the average life not so long. One consideration in adopting this design was that the open ends offered better facilities for tamping than ties of similar section with closed ends, like the Rendel tie, for instance. But notwithstanding this point in its favor, the section men have found that rather more labor has been necessary to maintain the steel-tie track in line and surface than that laid with wooden ties. The above record shows that corrosion has been only a minor cause of failure. Trouble from this cause has been experienced only in thickly populated districts, in tunnels, in manufacturing areas, or where the ballast was of such character that rapid corrosion might be expected. About 800 of these Webb steel ties were experimented with on the Pennsylvania R. R. for some years (including the year 1889), but the results were not satisfactory.

Iron Plate Ties.—The Denham-Olpherts cast iron plate tie, used on a number of railways in India, notably the East Indian; Delhi, Umballa & Kalka;

Eastern Bengal; Indian State; and Northwestern roads, consists of two flat-bottom cast iron ribbed plates 2 ft. long, 10 ins. wide and 9-16 in. thick, weighing 176 lbs., united by a tie bar ½ in. thick and 2 ins. deep. The fastening consists of two cast iron jaws weighing 26 lbs. and two pairs of gibs and cotters weighing 3.8 lbs. The outer jaw is cast integral with the plate and the inner one is adjustable. These ties are said to give good satisfaction. On the East Indian Ry., where they are the standard form of track support, 2,483,600 of them were in service in 1895. On this road the plates are cast, and the tie bars are rolled, from scrap metal. The annual breakage has averaged 0.64 per cent.

Pot Sleepers.—Another form of metal track support that is in extensive use, particularly in India, consists of cast iron pots or bowls laid open side downward. Locally they are known as "pot sleepers." The gage is maintained by tie bars transverse to the track, uniting pairs of bowls, and adjustment of the gage is made by variations in the widths of the keys which secure the tie bar to the bowl. The style of rail fastening on the India Midland Ry. consists of a lug cast on the bowl, to engage the flange of the rail on the outside, and for the gage side there is a jaw or clamp which is held to its work by a wrought iron key. Each bowl weighs 92 lbs. and the weight of the tie complete, including tie bar and fastenings, is 217 lbs. On the Great Indian Peninsula Ry. this style of track support is used almost exclusively. In 1901 the whole of the main line, aggregating 1750 miles of single track, was supported upon pot sleepers, and a large proportion of the sidings, aggregating

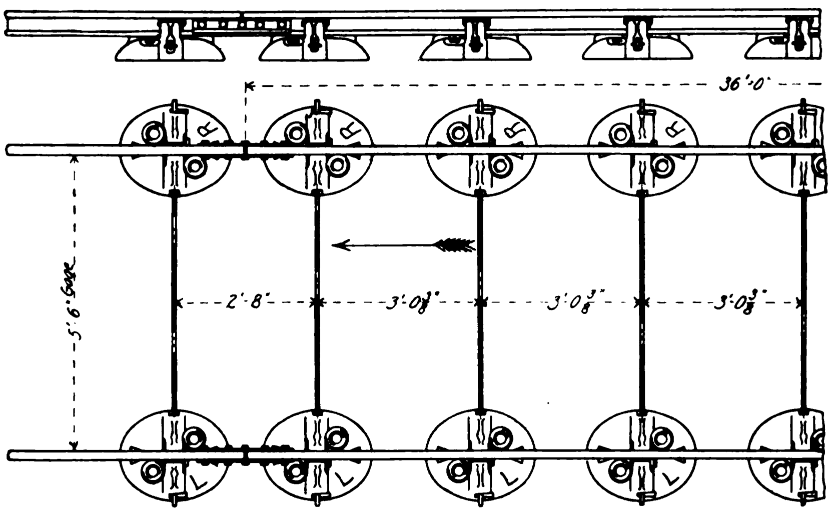


Fig. 488.—Cast Iron Pot Sleepers, Great Indian Peninsula Ry.

260 miles of single track, was of similar construction. Wooden ties were then used only upon bridges, and over such arches as had only a thin cushion of ballast between the crown and the rail level; and on two ghats, or mountain passes, aggregating 26 miles in length, where they were used mainly because the roadbed was rock. Just previous to the adoption of pot sleepers exclusively, in 1900, the proportions of the various kinds of ties in the track were as follows: timber cross ties (92 per cent of which were teak, having an average life of 13 years), 9.17 per cent; cast iron round pot sleepers laid prior to 1866, 11.36 per cent; cast iron oval pot sleepers laid since 1866, 79.47 per cent. It is seen that many of the pot sleepers originally laid in the line, more than 34 years previously, although of an inferior pattern to those then adopted as the standard, were still in use. A great many of these had been transferred, from time to time, from main line to sidings, in the course of continuous renewals of the former with the latest patterns of track material, and had thus passed through the "severe test of removal and relaying."

The pattern of pot sleeper now standard with the Great Indian Peninsula Ry. is shown in Fig. 488. It is known as the "R. & L." (right and left) sleeper and is laid under 82-lb. steel rails 36 ft. long. The pots are oval in plan, 24⅝ ins. over the long diameter and 20¼ ins. over the short diameter. When used on double track the style of construction of these pots (right and left) permits of both keys being driven in the same direction as the traffic. They have large "packing" holes in the top (for tamping) and the rail seats are cast on the pots. The weight of a "sleeper" is made up as follows: 2 pots, each 101 lbs., 202 lbs.; 1 wrought iron tie bar, 25.75 lbs.; 2 wrought iron gibs, 0.41 lb.; 2 wrought iron cotters, 1 lb.; total, 229.16 lbs. This sleeper was introduced in 1884, since when no other kind has been laid. The wrought iron tie bars used to connect the pots withstand corrosion very well, as none have been rejected on account of corrosion except at a few places near the sea, where they were placed in dirty, moisture-bearing ballast. At the joints (suspended) the pots are spaced 32 ins. centers, and under all other portions of the rail 36⅝ ins. centers. Under the heaviest traffic the ballast used is broken stone, but over a large mileage the ballast is sand of various qualities. In 1900 there were in service on this road four other patterns of pot sleepers, as follows: (a) one having plain round pots 22½ ins. in diam., with large packing holes, introduced prior to 1858; (b) one having ribbed round pots 22¼ ins. diam., similar to the foregoing, except for ribbing, introduced prior to 1858; (c) one having original "old" oval pots, 27x20¼ ins., without packing holes and with cells for wooden rest pieces, introduced about 1866, being made up of 2 pots, each weighing 93.3 lbs., and a wrought iron tie bar weighing 25¾ lbs., or a total weight, including gibs and cotters, of 213.8 lbs.; (d) one having "new" pattern oval pots 25x20¾ ins., with large packing holes, cells for wooden rest pieces, and strengthened chair jaws. The complete sleeper of this pattern is made up of 2 pots, each weighing 100 lbs., and a wrought iron tie bar weighing 25¾ lbs., or a total weight, including gibs and cotters, of 227.2 lbs. This sleeper was introduced about 1877. It thus appears that some of the oldest sleepers had been in service 42 years. Records on file since 1872 show the half-yearly renewals of pots, and the percentage per annum of breakages, as ascertained from them, is 1.66. This figure includes breakages due to derailments, and some removals due to regrouping of the several patterns of pots (different patterns, round and oval, having been laid promiscuously in the old days), so that the percentage is higher than that of actual failures due solely to ordinary wear and tear, and therefore represents the pots as having a shorter life than they really have.

In 1901 the Madras Ry. had 897 miles of main track and 149 miles of sidings laid with cast iron pot or bowl sleepers. The total number of pots then in service was 3,318,427, and the renewals for the preceding two years averaged 2.88 miles or 9135 pots per annum, which was 0.275 per cent renewed per annum. Timber ties of many descriptions of local wood were originally tried, but their life was very short, being only 4 to 5 years. These were replaced by creosoted pine ties sent from England, and these were after some years' trial replaced by cast iron pot sleepers, which are now used almost exclusively on this road, timber sleepers being used only on bridges, including masonry arches, and under switches and frogs. Cast iron pot or bowl sleepers were first laid on this road in 1861, and after 40 years of service most of these were still in the track. Prior to 1892 six patterns, varying in weight from 89 to 110 lbs. each, were used, but in that year a large number of drop tests were made on the pot sleepers then in use, by Chief Engineer E. W. Stoney, the results of which were described in a report by that gentleman in 1892. In 1894 he designed a stronger sleeper, with pots weighing 112 lbs. each, which is now standard, and is used to renew the older, lighter and weaker patterns as they become unserviceable. The details of the design of this sleeper are illustrated in Fig. 489. The heaviest engines in use are 6-coupled freight locomotives, with a wheel base of 15¼ ft., carrying 14½ tons on each axle, and a total load of 73¼ tons. Mr. Stoney states that these cast iron sleepers joined with wrought iron tie rods make an excellent road. To insure this, however, it is necessary that they be tamped with good, clean sand ballast. Broken stone has been found to be unsatisfactory for ballast. The standard ballast material is sand, covered with a layer of broken stone 1½ ins. thick to keep down the dust. The rails are of the bullhead pattern, 30 ft. long, and the sleepers are spaced 2½ ft. centers at the joints (suspended) and 36.66 ins. centers throughout the intermediate parts of the rail. The following extracts from a report by Mr. Stoney dated Aug. 5, 1899, on the relative life and cost of timber and cast iron sleepers, give some further information of interest:

"About 898 miles of the total 912 on the Madras Ry. are now laid with old-pattern pots weighing from 90 to 98 lbs. each, and 14 miles with the new pattern, 112 lbs. each. No person can at present say what the ultimate life of the component parts of our cast iron sleeper road is, the oldest portion put down in 1861, or 38 years ago, being much too short a time laid for any portion to have reached its life limit. In the absence of such positive data it seems to me that the only way to arrive at a fair conclusion as to the ultimate ages required is to take the actual renewals per annum of each item for the past few years, and compare those with the total number of each article laid during this time.......... From personal observation extending over a period of 30 years, in charge of permanent way, I can say that almost all renewals of pots were owing to their being found cracked or broken, hardly any being removed owing to rust or wear, those so taken out being chiefly in the salt depot, Madras, where the jaws dropped off. During inspections the road has been often opened out in all sorts of soil, and the pots, tie bars, etc., found practically free from rust, chiefly due probably to the use of sand ballast. Although our present average renewals show the probable life of a pot-sleeper to be 304 years, I have assumed an age of 60 years, only one fifth of this, in the calculations. The age of tie bars, gibs and cotters has been taken at 30 years, very much below that given from actual renewals. Keys have been assumed to last 6 years, steel rails only 36 years, fish plates 36 years and fish bolts 24 years.

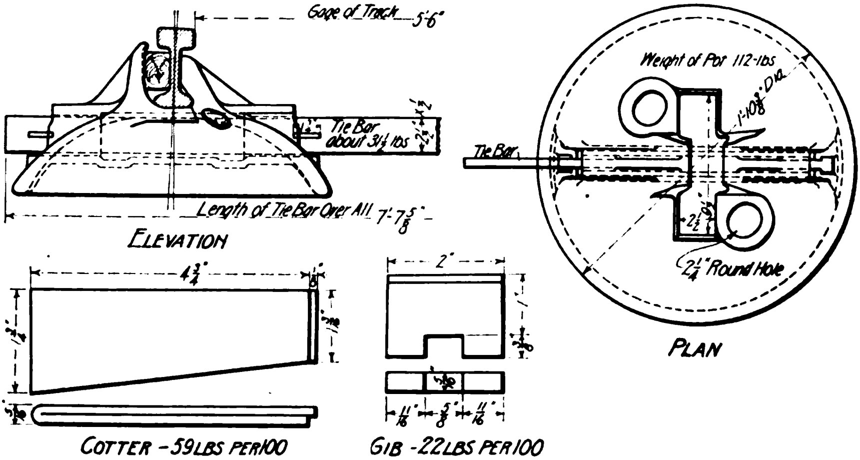


Fig. 489.—Cast Iron Pot Sleeper, Madras Ry.

"The relative capital cost at 4 per cent compound interest at the end of 56 years, of a pair of pot sleepers, with tie bars, gibs, cotters and keys costing Rs. 9.25, a jarrah sleeper costing Rs. 5.8, and lasting 14 years, and a junglewood sleeper costing Rs. 5.0 and lasting 7 years, is as follows: Rs. 166.45 for the junglewood, Rs. 109.71 for the jarrahwood and Rs. 83.18 for the pair of pot sleepers, no allowance being made for the scrap value of the sleepers at the end of their lives. This takes into account four renewals of the jarrah sleepers, and eight renewals of the junglewood sleepers, with compound interest. Another way of looking at the question is to compare the price which might be paid for the pots to make them equal in final capital cost to junglewood and jarrah. The result is that if Rs. 5 be paid for a junglewood sleeper lasting 7 years, Rs. 18.51 would be the value of a pair of pots lasting 60 years; and compared with a jarrah sleeper lasting 14 years, costing Rs. 5.8, then Rs. 12.20 could be paid for a pair of iron sleepers. These results show very forcibly the enormous influence the life of a sleeper has on its cost."

A comparative statement of the total annual cost per mile of 2000 sleepers represents the cost to be Rs. 1660 for the junglewood, Rs. 1100 for the jarrahwood and Rs. 653 for the pot sleeper (pair of pots), taking account of the value of the scrap at the end of 56 years. If the value of the scrap be not taken the cost for the pot sleeper is Rs. 832. The process of these computations, together with other information in detail, is shown in the Railway and Engineering Review for Apr. 6, 1901.

The pot sleeper is also in extensive use in the Argentine Republic. The form in use on the Buenos Ayres Great Southern Ry. consists of two cast iron bowls of oval plan, each 26 ins. long, parallel with the rail, and 18¼ ins. wide transverse to the track, connected by a wrought iron tie bar passing through the upper part of each bowl and secured by flat cotters 1¼ ins. wide and ¼ in. thick. The length of the bowl on top is 21¾ ins., the middle of the bowl being depressed like a saucer. The thickness of metal is ⅝ in. on top, 5-16 in. on the sides and 11-32 in. in the middle. The rail is secured by lugs and taper keys. The depth of the bowl under the rail is 5 ins. There are eight pairs of bowls per 25-ft. rail length.

Bowls or pots were at the first designed for use in sand ballast, under which condition they are said to give good satisfaction, as is also the case when laid on earth ballast or gumbo. On broken stone ballast they have in some cases been reported less successful, as already noted.

Features of Design and Maintenance.—Metal cross ties are usually made of mild steel, containing about a tenth of 1 per cent of carbon, and they are usually rolled, like rails, or pressed to shape from flat plates. Ties of the pot or bowl pattern are usually made of cast iron, although some of the ties of this type in India are of pressed steel. To preserve the ties against corrosion it is quite commonly the practice to dip them in some preservative like boiling coal tar mixed with turpentine or tar oil. After applying the coating the tie is sometimes dipped in sand, to give it a rough surface, so as to increase the friction of the tie in the ballast. Corrosion is most troublesome usually in tunnels, owing to the usual dampness in the bedding of the tie and to the corrosive effect of acids and gases from the smoke and the engine cinders. Ties laid in slag or cinder ballast or in salt or alkaline earth are also subject to corrosion of greater or less severity.

Bolts, with clips, clamps or jaws, and wedges, are quite common forms of fastenings, and there are various ways of effecting the adjustment or widening of the gage, as on curves. In some cases the adjustment is made by the use of different sets of clamps and bolts. In other cases the adjustment is effected by bolts with eccentric necks or eccentric washers. By making the bolt hole of a square washer out of center on two axes the four edges of the washer will be at different distances from the hole, and thus provide for four adjustments of the gage. With the Rendel tie the gage may be adjusted by placing keys on both sides of the rail, inside and out, or by placing a packing piece between the inner lug and the edge of the rail. On this tie the space between the tips of the fastening lugs is narrower than the width of the rail base, so that the rail must be canted in order to set it to place on the ties or remove it from its seat. It cannot therefore become detached from the ties by straight lifting should the keys slip out of place. In removing these ties from the track the rails must be taken up. The small end of the taper key is sometimes split, so that it may be spread open, to resist any tendency to work loose and slip out of place. With the clip fastening it is quite commonly the practice to use a bolt with a "T" head, secured to the tie by inserting it through a slot in the top table. The usual method of laying track where bolt and clip fastenings are used is to splice the rails and block them up high enough to leave sufficient clear space beneath to run the ties under. Men working in pairs then raise the ties to the rails and secure the fastenings, after which the track is ballasted. Under frogs and in switch leads, in connection with metal track, it is usual to lay wooden ties, but in some instances metal ties are used, such being the case with some roads in Germany and Switzerland.

As with wooden ties, so with metal ones, the question of maintaining a firm connection between tie and rail is in dispute. In order to prevent wear at the rail seat and resist creeping of the rails it is desirable to hold the latter down tightly to the ties. On the other hand it is undesirable to have any vertical movement of the ties in the ballast. One of the standing complaints in the use of metal ties in Germany is that the ties, held securely to the rail by their fastenings, rise and fall with the rail in its undulations and "grind the ballast to dust." To overcome this trouble the engineers of the Prussian State railways have made various experiments with loose fastenings. In one arrangement the fastening allows of a certain amount of vertical play (about 0.2 inch) between the rail and its seat, so that the undulating motion of the rail does not disturb the embedment of the tie in the ballast. Another arrangement consists of a wooden shim or cushion 1.3 ins. thick placed between the tie and a tie plate, with an allowance in the fastenings of about 0.2 in. (5 millimeters) of relative vertical movement for the rail. Both of these experiments are said to have resulted satisfactorily. The Eastern Ry. of France has used a tarred felt pad between the tie and the rail, to take the wear, keep the sand out and diminish the noise and jarring of the tie.

The tie with closed ends seems to meet with most favor, because it presents an end surface to resist lateral displacement. An inverted trough tie with closed ends offers a greater resistance to lateral displacement than a tie of solid section throughout, as the tie is then resisted not only by ballast piled against the end, on the exterior, but also by the core of ballast inside. Regarding the best ballast material for metal ties there is some disagreement in practice. Broken stone of the usual sizes is quite widely recommended and is extensively used for metal cross ties. The experience of the Mexican roads in this respect, however, is contrary to what is reported of results obtained in many other countries where steel ties are extensively used. On each of the three roads in Mexico whereon steel ties are used the officials emphatically declare that broken stone ballast of any size ordinarily in use is not suited to the maintenance of track laid with steel ties. How well a finer size of broken stone ballast might answer is not intimated, but gravel and sand seem to be preferred in any case. The explanation which most readily suggests itself is that broken stone, being less mobile in character than gravel or sand, is not so readily tamped into the hollow of the inverted trough tie. In some quarters, as elsewhere mentioned, broken stone has also been reported to be an unsatisfactory ballast for pot sleepers, which, for ordinary lifts in surfacing, are tamped through holes in the top.

In the work of ballasting, the material must be packed hard at the ends of the tie and under the rail seats, leaving the middle but loosely tamped. One method of accomplishing this is to place the ballast in two rows of heaps, spaced to correspond to the spacing of the ties. In laying the track the ties are placed across pairs of heaps and an engine is run over the track to settle them down into the ballast, which has the effect of packing and tamping it hardest under the rail seat. The ballast is usually filled in flush with the tops of the ties and frequently over the tops of them. It is said that after Boyenval-Ponsard steel ties have been some time under traffic the cores of ballast formed inside the two channels which open downward adhere to the tie, and are lifted with it when the tie is raised, thus giving virtually a flat under bearing surface which can be tamped as readily and as thoroughly as the bottom face of a wooden tie.

On track laid with metal ties the expense of maintaining line and surface during the first two or three years is usually more than that for wooden ties, but as the ballast becomes compacted under the ties the maintenance expense gradually decreases, and after some years the showing on some roads favors the metal tie, while on others the reverse obtains. On the Netherlands State railways the average annual cost of track work has been $141 per mile where wooden ties were used and $97 per mile where steel ties were in service. On some of the French lines the track labor accounts of six places for a period of 11 years showed an average of $112 per mile for track laid with wooden ties and $83 per mile for track laid with steel ties. The volume of the traffic over the ties is not stated. On other lines where steel ties have been tried, particularly where the traffic has been heavy, comparisons of maintenance costs have brought the steel tie into disfavor. Persons interested in the maintenance of track on steel ties should read an article by A. Flamache, on "Uses of Metallic Ties," published in the Railway Review for Oct. 14, 1893, wherein are pointed out some of the difficulties which stand in the way of economical maintenance with metal ties of inverted trough section.

Duration.—The life of steel ties is generally estimated at 30 years. So far as the matter of corrosion is concerned this is probably a fair estimate for ties laid in favorable soils or ballast, but of course the design of the tie, particularly with respect to its vertical stiffness, should greatly affect its strength, which is important as bearing upon the question of failure by breaking or cracking. Twelve years is the estimated average life of large numbers of pressed steel ties doing service in India, but the conditions of exposure are not stated. There are but few reports of metal ties which have actually been in service as long as 30 years, which, however, may be due to the fact that the early ties have probably in most cases been displaced by ties of improved design. In the year 1900, 10,000 iron ties of the Cosijns type (an I-beam laid with the web horizontal) which had been in use 35 years between Deventer and Olst, on the Netherlands State railways, under a traffic of 210,000 trains, were still in good condition, and the oak rail-bearing blocks in the top channel were being replaced by metal blocks, with the expectation that the ties would last many years longer. These ties, which weighed 125 lbs. in 1865, had lost only about 9 lbs. each by corrosion and wear in the 35 years. The ballast was gravel and sand, the maximum locomotive wheel loads 7 tons, and the speed of trains 46 miles per hour. Some Vautherin iron ties weighing 74 to 98 lbs., in the line from Algiers to Oran, in northern Africa, were still in the track after 26 years, under a traffic of 70,000 trains, maximum speed 31 m. p. h. Some Post ties on the Netherlands State railways were still in service after 25 years, under a traffic of 137,500 trains.

Cast iron corrodes far less rapidly than wrought iron or steel, under the same conditions of exposure, and cast iron ties are noted for their durability. Cast iron pot sleepers in India have been found to be serviceable after being under traffic more than 40 years, as elsewhere stated. It is of interest to note that in the experience on foreign railroads no serious loss of steel ties occurs from derailed cars. Ties which become bent from such cause are removed from the track and are usually straightened by hydraulic press without difficulty or without fracture. The wear at the rail seats of steel ties is said to be not serious, but for heavy traffic, especially on curves, tie plates are recommended. In calculating the economy of the metal tie it is important to take into consideration the fact that when worn out, if not thoroughly corroded, they have considerable value as scrap, whereas old wooden ties can seldom be disposed of to any profit.

204. Locomotive Counterbalance Experiments.—In the mechanical laboratory at Purdue University, Lafayette, Ind., there is an ordinary 8-wheel passenger locomotive mounted to run a tread mill, each pair of drivers being supported upon a pair of wheels of about the same size turning together upon an axle journaled in a pit. The locomotive is held fast, and as the driving wheels revolve they turn the supporting wheels in the pit, so that somewhat similar conditions obtain as when running upon ordinary track. By applying braking power to the pit wheels the conditions imposed are similar to those which obtain when the locomotive is pulling a load. The locomotive tested had drivers 63 ins. in diameter, fully counterbalanced for both revolving and reciprocating parts. The weight of the reciprocating parts on each side of the engine is 812 lbs., including the main rod, weighing 344½ lbs. Four tenths of the weight of the main rod was considered as a reciprocating weight, so that the excess balance for each side was taken at 605.3 lbs., 204.5 lbs. being placed in the main wheel and 400.8 lbs. in the rear wheel, or practically 66 per cent of the balance for reciprocating parts in the rear wheel. The weight of the side rod is 278 lbs.

The method of testing the behavior of the wheels at high speed was to pass a soft iron wire of .037 in. diameter under the drivers while they were in motion. The wire was straightened and cut into lengths of 20 ft. and fed under the wheels through a ⅜-in. pipe fixed in place just in advance of the point of contact of the driver. To connect the phase of the driver's motion with the effect produced on the wire the tread of the driver was nicked with a cold chisel, so as to stamp the wire at the point passing under that part of the wheel. The results of greatest interest were obtained under the rear wheel, which was the one most heavily counterbalanced. At a speed of 59 miles per hour this wheel, for an instant in each revolution, barely touched the wire, as indicated by the absence of any flattening effect. At a speed of 63 miles per hour it was found that the driver did not touch the wire for 41 ins. in each revolution; and at 65 miles per hour the length of wire not touched by the driver was 46 ins., or corresponding to about ¼ revolution of the driver. The maximum lifting effect was found to take place just after the counterbalance had passed its highest point. As recorded by the marks on the wire, the rise of the wheel from the track was more gradual than the descent, which would be expected from the inertia in the mass to be lifted. The flattened portion of the wire was uniformly about .01 inch in thickness for about half the revolution, and rolled so thin by the normal pressure of the wheel as to be not visibly affected by further increments of pressure. For this reason the damaging effect produced by the dropping of the wheel when the counterbalance passed below the center could not well be determined or estimated.

Under the forward driver no results were obtained which gave evidence that the wheel had left the track, although the wires used showed some variation in thickness, indicating that the wheel pressure had varied. From calculation it was estimated that the forward wheel ought not to lift from the track at a speed less than 80 miles per hour, but this speed could not be attained. It was ascertained that the rocking of the engine upon its springs affected considerably the vertical lift of the drivers, sometimes acting with them and accentuating the lift and sometimes opposing them and counteracting the lift; while at other times the rocking seemed to have no effect on either driver, as shown by wires passed under both at the same time. Observation was also made of a vibration in the driver of .002 to .004 inch in amplitude within 10 ins. of wire, or corresponding to .01 second in time.

Some of the conclusions drawn from this series of experiments were summed up by Prof. Goss, in substance, as follows: (1) Wheels counterbalanced according to the usual rules, where the revolving parts and from 40 to 80 per cent of the weight of reciprocating parts are balanced, the counterbalance being equally distributed among all the connected wheels, are not likely to leave the track unless the speed is excessive; (2) A wheel and load weighing 14,000 lbs., carrying a counterbalance of 400 lbs. in excess of that required for the revolving parts alone, will lift from the track at a speed of 310 revolutions per minute; (3) The rocking of the engine on its springs may assist or oppose the action of the counterbalance in lifting the wheel; (4) The contact of the moving wheel with the rail is a succession of impacts.

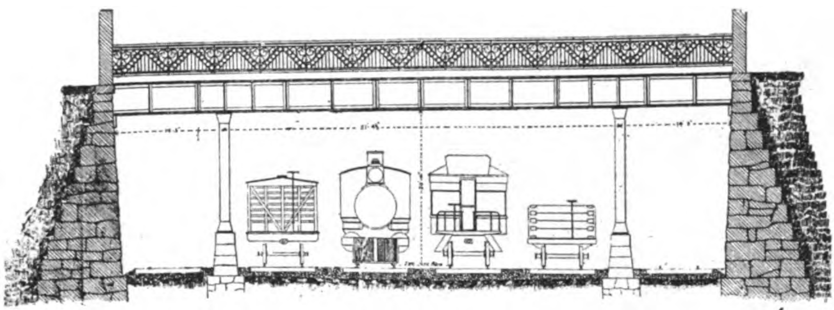


Fig. 510.—Section of Subway, P. & R. Ry., Philadelphia.

As the locomotive in these experiments was supported over masonry foundations, some engineers have raised a question as to whether, under the conditions, the results can be considered applicable to track on roadbed of the ordinary yielding character; and it has been asserted, without any offer of proof, however, that on account of the elasticity of the track a locomotive driver could not lift from the rail. I fail to see the force of these points. The experiments certainly show what the tendencies are when the counterbalance is excessive or improperly distributed, and as long as we know that great pressure and damage are caused by this overbalance it is of relatively small consequence whether or not the wheel actually lifts from the rail.

Those who may desire to study the subject of locomotive counterbalance more in detail are referred to papers by Mr. David L. Barnes and Prof. W. F. M. Goss, presented before the American Society of Mechanical Engineers, in December, 1894, and published in Vol. 16 of the proceedings of that association for 1894-95; also to Vols. 29 and 30 (1896 and 1897) of the proceedings of the American Railway Master Mechanics' Association, pages 148 and 117, respectively.

205. Track Elevation and Depression.—Some of the most intricate work of track depression which has been performed in this country was the lowering of the tracks of the Philadelphia & Reading Ry., in Pennsylvania Ave. and Noble street, between Poplar and Thirteenth streets, in Philadelphia, completed in 1899. This work accomplished the abolishment of 17 grade crossings at street intersections, by the construction of a subway and tunnel for the tracks, which involved also the reconstruction and lowering of about 3½ miles of sewers, much of which had to be done by tunneling 25 to 45 ft. under the surface. Between Thirteenth and Twenty-second streets there is 4180 ft. of open subway 80 ft. wide, carrying six tracks (Fig. 510), widening out at points into depressed freight yards. West of this there is a 4-track tunnel 2711 ft. long, west of which there is another open subway 2150 ft. long, the total length of the depression thus being nearly two miles.

While the work on the eastern half of this depression was being carried on (between Thirteenth and Twenty-second streets) traffic was maintained on a system of temporary tracks laid in Hamilton St., running parallel and one block distant. From Twenty-second St. westward, or over the western half of the depression, comprised by the tunnel and the open subway beyond, traffic was maintained while work was in progress by shifting the old tracks to the south side of the avenue until the north wall of the tunnel or subway had been constructed in a trench 33 ft. deep, after which the temporary tracks were shifted to the extreme north side of the avenue and supported partly upon the newly constructed wall. The material was then excavated, the south wall of the tunnel built and the open space arched over to form the tunnel, as illustrated in Fig. 511. This tunnel is 52 ft. wide and the headway over the top of the rail is 22 ft. The rise of the arch is 8 ft. 8 ins. and the radius of the arch 43 ft. 4 ins. The ring of the arch is of brick, 3 ft. thick at the crown and 4 ft. thick at the skewbacks. The clearance between top of rail and bottom of girders at street viaducts (Fig.510) is 20 ft.

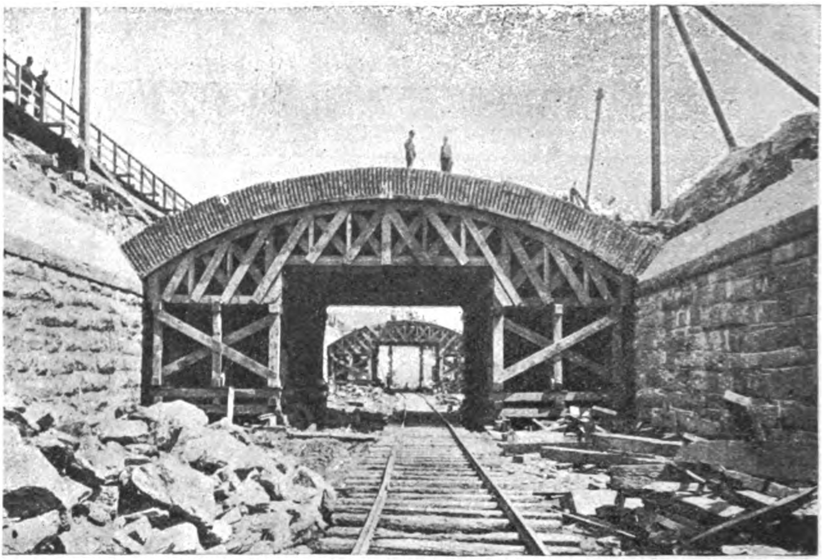


Fig. 511.—Method of Constructing Tunnel Arch, P. & R. Subway, Philadelphia.

In the construction of the retaining walls along some parts of the subway the fronts of high buildings had to be underpinned, and along other portions of the subway it was found necessary to construct temporary fronts inside the buildings, remove the old front walls, construct retaining walls upon the building line, and then reconstruct the front walls of the buildings. At still other points the retaining wall passed within the foundations of some of the buildings adjoining the avenue, so that it became necessary to remove a portion of the building, construct a temporary front, and after building the retaining wall construct a new front with the retaining wall for a foundation. The entire work of lowering the sewers and constructing the subway was in progress five years and cost, including damage to property, $6,000,000. Full details of the work. with illustrations, were published in the Railway Review of May 23, 1896, and in the proceedings of the Engineers' Club of Philadelphia for February, 1899.

In depressing 3.65 miles of four-track road on the Boston & Albany R. R., in Newton, Mass., completed in 1897, traffic was diverted during the excavation of the subway to two temporary tracks laid along one side of the right of way, part of the distance on trestle. Excavation was first made for two of the permanent tracks, which were laid, and traffic transferred to the same, after which the excavation of the subway was completed and the remaining two tracks were laid.

The Sixteenth Street Subway, in Chicago.—Another very complicated piece of work of changing the elevation of tracks, perhaps the most difficult ever

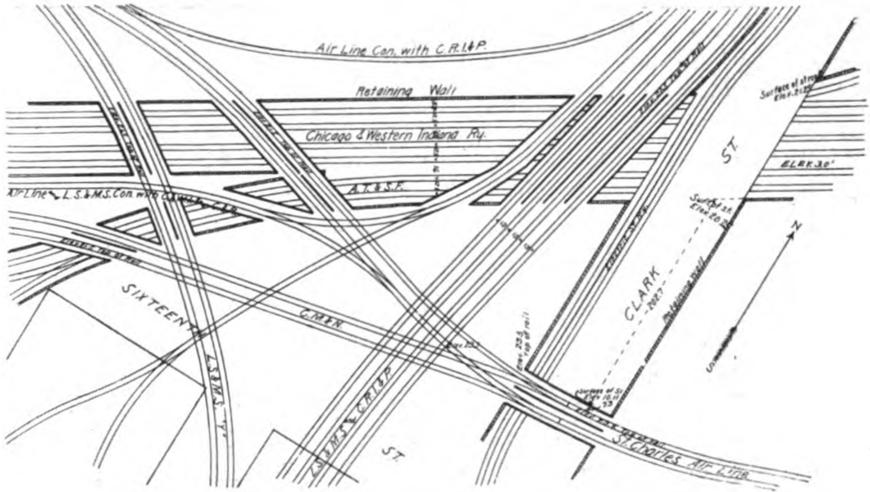


Fig. 512.—Sixteenth Street Crossing and Subway, Chicago.

undertaken in this country, was the combined elevation and depression of a network of tracks in the vicinity of Sixteenth and Clark streets, in Chicago, in 1898. The complicated nature of the conditions encountered at this point may be appreciated to some extent if the reader will picture to his mind four main tracks (Fig. 512) running north and south*, paralleled by a double-track street railway a few feet distant, all of which were crossed at grade by four main tracks running east and west**, and all of the foregoing tracks again crossed diagonally at grade by six main tracks running from northeast to southwest***, which for brevity and convenience, will be called the "northeast" tracks. The tracks crossing one another in this vicinity enclosed a triangular area measuring from 300 to 400 ft. on each side. Beside these 14 main tracks there were numerous interconnecting tracks used for switching purposes, so that, altogether, within a space covered by a radius of 300 ft. there were found 113 single-track crossings of steam roads and seven slip switches. The various lines of tracks were used by the trains of 15 different railroads, and the records show that the traffic passing this crossing averaged 5000 cars and 500 locomotives daily, not to consider that one of the busiest street car lines in the city, crossing 13 of these tracks, was operating cars and trains of cars on two minutes' headway over the crossing, and the congestion of vehicular traffic in the street (Clark St.) was very great.

The plan decided upon and carried out was to depress the six northeast tracks about 9 ft. in a subway about 1000 ft. long, elevate the four north and south tracks and the four east and west tracks about 10 ft., and to carry the street with its street car tracks over the depressed northeast tracks on a 4½ per cent grade and down under the elevated east and west tracks on a 5 per cent grade. The first work undertaken was to lay foundations for the concrete retaining walls and to build stretches of wall in such places as the tracks could be temporarily diverted for the purpose, the uppermost consideration which governed the work from beginning to end being to keep the traffic moving. After

*Operated by the Chicago, Rock Island & Pacific and the Lake Shore & Michigan Southern roads, and used also by the trains of the New York, Chicago & St. Louis Ry.

**The St. Charles Air Line (two tracks), operated by the Illinois Central, Michigan Central (freight), Chicago, Burlington & Quincy (freight), and Chicago & Northwestern (freight) roads; and the Chicago, Madison & Northern Ry. (two tracks).

***The Atchison, Topeka & Santa Fe Ry. (two tracks) and the Chicago & Western Indiana Ry. (four tracks). The tracks of the latter road carried also the trains of the Chicago & Erie, the Grand Trunk, the Wabash, the Chicago, Indianapolis & Louisville and the Chicago & Eastern Illinois roads.

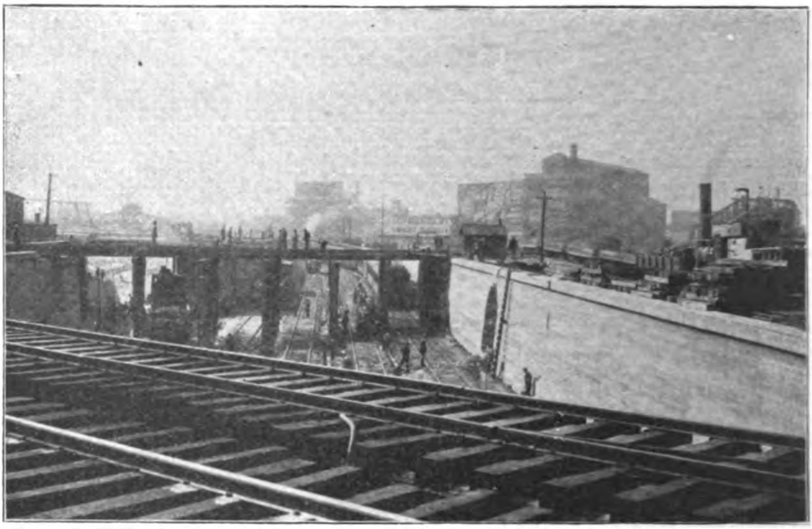


Fig. 513.—Progress View, Sixteenth Street Crossing and Subway, Chicago.

the retaining wall along the northerly side of the northeast tracks had been constructed (except where crossed by the east and west and the north and south tracks), two of the north and south tracks, two of the east and west tracks, three of the northeast tracks and both of the street railway tracks were abandoned and all of the remaining tracks were elevated simultaneously on sand filling, to the final elevation. The north and south and the east and west tracks were to remain elevated, while, as previously stated, the northeast tracks were to be depressed, the scheme of elevating them being to carry the traffic until part of the subway should be excavated and tracks put in order therein.

The northerly side of the filling for the elevated northeast tracks was retained by timber cribbing based on the second northeast track from the north side. The elevation of all the tracks was accomplished while traffic was being moved over them, and as soon as the final elevation was reached piles were driven through the filling for the support of the north and south and the east

Fig. 514.—Depressed Tracks of the C. & W. I. and the A., T. & S. F. Roads at Sixteenth Street Crossing, Looking Northeast.

and west tracks where they crossed the space to be excavated for the subway. In the meantime excavation had been made along the northerly retaining wall of the subway for one track, and as soon as the elevated tracks crossing the site of the subway had been supported upon piling the filling underneath the same was removed and the track was connected through the subway. One of the elevated northeast tracks was next abandoned, the filling material underneath it removed, using the track through the subway as a working track, when a second track was laid through the subway and part of the traffic trains over the northeast tracks were diverted through the subway. One by one the elevated northeast tracks were abandoned, as the excavation through the subway was widened out, until all of the northeast tracks were relaid in the subway, when the principal object of the scheme was accomplished. The retaining walls for the subway had been carried up simultaneously with the elevation of the tracks, so that the work which now remained to be done was the placing of permanent bridges in substitution for the pile trestles across the subway.

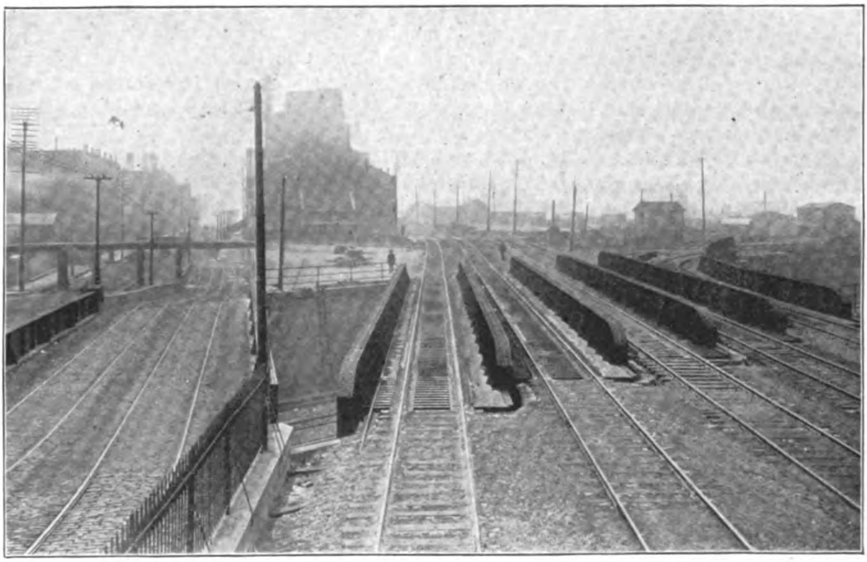


Fig. 515.—Elevated Tracks at Sixteenth Street Crossing and Subway, Chicago.

Figure 512 shows the location of the various tracks of the crossing after the subway was completed. The heavy lines represent plate girders. The tracks through the subway were depressed to an elevation of only 3 ft. above city datum. The other elevations noted in the illustration refer to city datum. Figure 513 is a view looking southwest along the subway while the tracks across it were still on temporary pile supports. The tracks in the foreground are those of the C., R. I. & P. and the L. S. & M. S. roads; those on the pile trestle are the St. Charles Air Line. Figure 514 is a view looking in the opposite direction (northeast) through the subway after the plate-girder bridges had been put in to carry the elevated tracks. The tracks on the lower level are those of the C. & W. I. R. R. The girders supporting the tracks rest upon two lines of columns intermediate between the side walls of the subway, the tracks each side of each line of columns being 16 ft. between centers; otherwise the spacing between the tracks is 12½ ft. The distance from the face of each side wall to the center of the nearest track is 8.3 ft. Later on the column supports for elevated tracks were walled in with concrete piers, as shown in Fig. 445, which is another view of this subway. Figure 515 is a view taken when the work was nearly completed, showing all the lines of railway involved in the elevation and depression of the tracks, but not all of the points of crossing. Beginning at the extreme left of the figure a view is had of Clark street, the portion of the street devoted to vehicular traffic being separated from the portion utilized by the street railway tracks by a girder. The street railway tracks appear next on the right. The street is carried over the A., T. & S. F. and C. & W. I. tracks and under the tracks of the St. Charles Air Line, the latter appearing on a temporary trestle crossing the street-car tracks. Next to the right of the street-car line is seen the four tracks of the L. S. & M. S. and C., R. I. & P. companies, each track running between a pair of girders. The track at the extreme right is a branch line connecting the C. & W. I. and L. S. & M. S. roads.

All of the important details involved in the work are too numerous to receive attention in a volume of this kind, it being sufficient to point out the ruling principle in the plan of the work; which was to first elevate simultaneously the tracks running in all of the three directions, in order to keep the enormous traffic moving unimpeded, when piles could be driven through the sand filling for the support of all the tracks crossing the space to be excavated for the subway, after which the subway could be excavated, first for one track, and gradually widened a sufficient amount for one track at a time, until finally the subway was completed and all of the tracks to be depressed were laid therein. The details of the work are exceedingly interesting to persons wishing to study methods of moving a very large traffic over temporary tracks in the presence of extensive and complicated engineering operations. For a full account of the whole undertaking the reader is referred to the Railway and Engineering Review for May 29, 1897, Nov. 19, 1898, and March 11, 1899; the Railway Age for July 29, Aug. 12, Aug. 26 and Nov. 25, 1898; the Engineering News for July 14, 1898 and Apl. 13, 1899; and the Journal of the Western Society of Engineers for December, 1898. The files of these publications for the years 1895 to 1902, inclusive, and the October and December, 1898, numbers of the Journal of the Western Society of Engineers contain a pretty complete account of all the track elevation work performed in Chicago up to the end of the year 1901.

206. The Training of Roadmasters.—In the introductory section of this volume it is stated that the maintenance of railway track is engineering, from which it may be reasoned inferentially that the man who is master of such work is an engineer. The trend of things late years has been to associate the work of track maintenance more closely with the engineering department of railways, or at any rate more closely with engineering methods, which is, of course, a move in the right direction, being in line with progress both for efficiency and economy. Growing out of this change of affairs there has arisen no little discussion and some question as to which of two classes of men, each alone considered, is better qualified for the position of roadmater—the engineer or the trackman. Most readers are familiar with several definitions for the term engineer, or civil engineer, but as pointed out in this connection we readily understand that reference is had to a man trained in mathematics and in the handling of surveying and drafting instruments, as applied to railway location, construction and measurements. When we speak of a trackman as a competitor with the engineer for the position of roadmaster we are understood to mean a man having at least a good common school education, whose experience has covered all the detail operations of track work, but particularly track maintenance. It goes without saying that he should be competent not only as a section foreman, but be capable of supervising the work of a number of foremen in charge of track. As track maintenance is an important branch of engineering it is worth while to consider the relation of these two classes of men to the work.

Since most engineers in these days are college-trained men it is well to analyze their antecedents, for on the part of the so-called "practical" men there is a good deal of prejudice against college men in general. As usual, enthusiasts on the subject carry matters to extremes in making comparisons. It requires only ordinary powers of observation to discover that there are two types of so-called educated men. There are men of the ornamental variety who apparently never survive the pedantic influences of their college days, and among this class may be found some men who can parade the degree of civil engineer. They are usually much concerned about matters of "esprit de corps," "ethics," etc., and they lament the fact that engineers are not able to maintain a professional standing on a level with lawyers and physicians. By such and other characteristics they are easily recognized, and their attitude undoubtedly has some tendency toward lowering the popular estimation of college men in general. Many who undertake to defend the college standpoint handle the truth too timidly. It is an indisputable fact that many college graduates, in scientific or technical as well as in classical lines, have neither capacity nor disposition for business responsibility. It is needless to remark that there is no demand for men of this type on railroads, where, above all things else, successful men must be practical. But such shortcomings are personal qualities, and they should not operate to prejudice the opportunities of college-bred men as a class, the majority of whom are serious-minded, industrious men, who could succeed in spite of a college education, but to whom such a training has been much of an opportunity and who have been broadened and benefited in many ways. Any man who is worth a college education will always be the better for it. There can be no doubt about that. This type of man is inclined to make the best of any opportunity he can get, he will seek to apply his knowledge to business ends, and in time he will become well acquainted with business affairs and methods. There need be no concern about college-trained men who are the right kind of men to start with.

The roadmaster should be an educated man; at least educated along the lines of his work; not necessarily a man of learning, in a strict sense of the term, but a man who has a trained mind, who reads and thinks, and who can comprehend at least the elementary facts of science; a man who is able from his breadth of view, to seek out knowledge, judge of it fairly, and know just how to apply it to his own ends. In favor of the engineer it may be said that his knowledge of mechanical principles, the resolution of forces, the strength of materials, the location of roads, the elements of curves and their computation, and other kindred information possessed by one worthy to be called an engineer, can be of service to any man having charge of track. While such knowledge is not called upon constantly in discharging the duties which engage the roadmaster's attention for the most part, there are occasions when it is in demand; and it certainly broadens his conception of things and enables him to comprehend all of the principles, calculations and manipulations which enter into roadbed and track construction. The man who has a knowledge of fundamentals is also better able to adapt himself to changing conditions than one not so informed and he is therefore so much the more independent of circumstances. In order to do accurate and reliable engineering work one must be able to check up computations, but a person who cannot comprehend the mathematics involved in engineering formulas or who cannot understand their demonstration, is not generally able to check either himself or his work.

The true engineer is a man trained to think with mathematical precision, who has an instinct for searching out the true relations of things and for properly weighing his facts in making comparisons; who is able to discriminate between cause and effect and able to judge of the proper limits of precision in his computations and in his measurements. If with such a training he has opportunity for combining with it the practical experience of any line of work, it ought to follow that, taking men as they are found, he should develop more rapidly and achieve a higher usefulness in the chosen calling than the man without an engineering training. With his ideas regarding system and his direct processes of thought he ought to be able to grasp readily a great deal of knowledge which the man not so trained is obliged to learn by slower process in the hard school of experience. These after all are the most valuable qualifications of an engineer for the management of track maintenance. While there are some questions of live interest in maintenance of way affairs which any engineer or surveyor ought to comprehend more readily than the trackman who does not possess a knowledge of the application of mathematics, still they are but relatively few in number. The advantage enjoyed by the engineer in respect of his education is derived not so much from his knowledge of technical matters as from his training in accurate and systematic methods of thinking; for no man who is not a careful thinker can expect to solve readily the problems which constantly arise in consequence of the changed conditions of train equipment and the general progress which comes about through modifications in track materials.

Such qualifications are therefore all very good, and undoubtedly essential to the highest usefulness, but by themselves they do not necessarily enable the possessor to assume executive control of parties of laborers on work which involves so many important details as does the maintenance of track. On any well constructed road surveying is, comparatively, but a small part of the maintenance work, and but little knowledge of the work and details of track maintenance can be gained with the transit, or at the drafting board. The cost of hand labor in most lines of engineering work is many times the cost of the head-work, and in track maintenance this is particularly so. The largest item in track maintenance is labor, constituting more than 60 per cent of the entire expense. Therefore, one of the most important things the roadmaster must oversee is labor; and men who have stood toil and exposure are usually considered the most competent in this line. It is natural to infer that the man who has had an outlook upon life from the laborer's point of view would be expected to possess some qualifications for overseeing and instructing laborers which would not ordinarily be found with men who have not had this experience.

It is frequently asserted that engineers as a class are so accustomed to precise figuring and exact methods of work that their training affords but little opportunity to develop capacity for handling men, who are not exact instruments; and it is a standing criticism of engineers that they are lacking in executive ability, and in capacity for handling ordinary business affairs. However this may be there can be scarcely a doubt on one point, and that is that trackmen are in possession of a vast amount of knowledge, gained from experience, which every man ought to have who assumes to take direct charge of the track forces. Some occasions under which a demand for special knowledge of track work is liable to arise are the selection and appointment of competent and reliable section foremen; the selection and purchase of suitable track tools; and in judging as to the progress and results which should be expected of the different foremen. In order to pass upon the matter last named the roadmaster must be able to estimate closely the amount of work a man can accomplish in a given time, at any of the multitudinous kinds of track work, and in this he can hardly succeed unless he is familiar with all kinds of track work. And then, to be fair, he must understand the nature of the difficulties which trackmen sometimes have to encounter in their work. He will also be called upon at times for instructions, which he cannot give intelligently unless he is familiar with track work. The most useful roadmaster is the man who can combine with executive talent the ability, upon occasion, to "set a pattern" for his foremen, or put himself in their place. He then ranks as a teacher, whereas if the case be otherwise he will be regarded merely as a critic, and his men will respect his opinions accordingly. On such considerations as these the experience of the trackman should not be ignored in appointing roadmasters.

In favor of the trackman it may be said that the man who has worked up from the bottom, had charge of a section, and who has been with work trains, is able at the start to take hold of things which he has done himself and of which he ought to have knowledge superior to that of the average of his subordinates; while the man without such experience must necessarily rely largely upon the judgment of his subordinates, until they teach him how to maintain track. He cannot, therefore, take hold at once and "push business" as the trackman can, for it takes some experience to enable one to discriminate wisely in the use of knowledge acquired from others. As between the two men, both being capable in their lines, there can be no doubt but that the trackman is far more competent to assume the duties of roadmaster than the engineer who is inexperienced with track work. The logical conclusion of the whole matter is that men are needed who can combine the training of the engineer with the experience of the trackman.

In justice to many roadmasters who have succeeded well in charge of track —the old school of roadmasters, if you choose—it must be conceded that among their number may be found men of fine judgment, well informed on matters pertaining to their work, men who think and study and who are able to reason straightforward and arrive at conclusions. Still, of these men it should be said that could they have had the advantage of a technical education they would have advanced to higher positions than that of roadmaster. All departments of railway work are progressing along scientific lines and coming roadmasters who hope for the largest success must fall in with the general advance.

Although railway officials are coming to recognize more and more the necessity of employing men of engineering training in the track department, there seems to be no united opinion as to the best course these men can pursue to sufficiently acquaint themselves with the details of track maintenance. One idea which prevails to some extent is that young men of this class, can, after a few years' observation of track work, either as surveyors in the regular corps, or as clerical employees in the maintenance of way department, or as assistants to the roadmasters, in some capacity, qualify for positions in charge of the work of maintenance of way. Another idea is to appoint engineers from the regular corps, with supervisors as assistants, who come in direct charge of the section foremen. The supervisor is supposed to be an expert trackman, so that any man who passes for an engineer may, with the support of one or more supervisors, get along for a time whether he knows anything about track from experience or not. In many cases of this kind the apprenticeship or the arrangement is of the nature of an extra or specially created position, tending toward an overabundance of officials. In course of time some of these men do well, but it costs a railway company something to educate to the duties of roadmaster a man who has not been a practical trackman, and in some cases it costs more than the man's technical education ever amounts to. While it is true that engineers in charge of, or associated with, construction work, such as is found in connection with change of grades and location, and work of this character, where some study must be given to the organization of the working forces, and the devising of plans to avoid delay to the traffic, ought to learn some things of practical value, still they do not come in direct contact with the laborers, and many of the most important lessons for a young roadmaster are absent. It is also too frequently the case that the laborers engaged on such work are unfamiliar with the language of the country, and, possessing no skill in the use of track tools, are driven around like so many cattle, direction as to the work being given in a broken tongue, more or less violently, perhaps, or partly by means of signs, gesticulations and other crude methods of communication. The engineer in contact with such a horde has but little opportunity to learn the character of English-speaking trackmen and how they should be dealt with—which knowledge is of inestimable value to a roadmaster, who must be an executive officer in the highest sense of the term.

It must be admitted that the tendency of the times is to divide up the duties and responsibilities falling to the office commonly known as that of roadmaster. This system is recognized wherever the organization comprises a supervisor of track and a master carpenter reporting to a division engineer who reports to the division superintendent. Where formerly there was a roadmaster and a master carpenter (or superintendent of bridges and buildings) both reporting to the superintendent direct, by the arrangement referred to the engineer now fills an intermediate position, being an "extra official," so to speak. The supervisors are recruited from the most intelligent and most industrious class of section foremen, and the master carpenter likewise from the bridge foremen of carpenters or of erection gangs. So far as the position of either of these is concerned, a technical education is not necessary—the man with the broadest experience in track or bridge work, with a fair common-school education, is, generally speaking, the best fitted. The division engineer to whom they report must be no other than a thoroughly trained engineer, whose duty it is to work out those technical matters which the supervisor and master carpenter are not supposed to be able to do, or, at any rate, are not expected to do. Of course it goes without saying that, according to the theory on which the organization is based, neither (the "practical" men or the engineer) can be dispensed with. Although the practical operation of many of the large railway systems of the country seems to controvert this proposition, the tendency is nevertheless as stated at the outset. An unfavorable aspect of the situation is that the so-called modern tendency presumes upon the necessity for multiplying offices.

Having followed the situation up to this point one is readily led to inquire whether, in this land of opportunities, it is reasonable to expect that men will undertake to acquire a knowledge of both track work and engineering; that is, on any such general scale as will meet the demand for this dual training. So far as opportunity exists there is, of course, every opening possible for any civil engineer who wishes to acquaint himself with methods of track construction and maintenance, and there is no hesitation in saying that the man who aspires to the position of roadmaster could employ his time for a year or two to no better advantage than by willingly engaging in the actual work of handling track tools. The man who will apply himself assiduously in this manner must without doubt become better fitted as a supervisor of track maintenance, in all its particulars, than he could hope to attain in any other manner. But good advice as this may be there are but few engineers who have ever resorted to such a course of preparation. The fact of the matter is that after graduation at college, whence most engineers come, the student of track engineering is beginning rather late to learn methods of work so thoroughly grounded in manual labor. To a person at this period there is a natural dislike to the performance of menial service, notwithstanding the nature of the inducement.

Nevertheless such courses of instruction have been inaugurated on a few roads of the country, notably on the Illinois Central R. R. On this road there is a system of track apprenticeship, introduced in 1897, by Mr. John F. Wallace, later general manager, whereby young civil engineering students and graduates from colleges or technical schools, and others from high schools or manual training schools, are taken into the track service as ordinary section laborers. After a year or two of practice those who show the right kind of ability are advanced to the position of section foreman or are taken into the engineering corps as rodmen, chainmen or transitmen. They then stand in line of promotion for such positions as assistant engineer, supervisor and roadmaster. The position last named is equivalent to that of division engineer or engineer of maintenance of way on other roads, and from it men have been frequently promoted to the grade of division superintendent. On this road track apprenticeship is the "doorway to the engineering department," and success by this route means "the survival of the fittest," for there have been many who have dropped out after beholding the serious aspect of a railroad career. A similar system was inaugurated on the Southern Pacific road, in Texas, by Mr. E. B. Cushing, while resident engineer, some years ago.

In a general sense, this process of "natural selection" has been but little tried, as yet, owing quite likely to the disinclination of both college men and railway officials to try the experiment, and the results have not been numerous enough to warrant any prediction as to the extent to which it may be put in practice in the future. The subject has been discussed a good deal by college professors, solicitous of opportunities for their students, but on their part there seems to be a desire that railroad companies should bind themselves to some agreement promising college students who undertake apprenticeships in track work some desirable position as soon as they have shown their fitness. On the face of things such an agreement could hardly be expected of a railway company. Young men seeking positions in maintenance-of-way work should not expect to be nursed. Men looking for such positions should have stamina enough to go to work with a will and take their chances of promotion with the rest of the employees. It is to be assumed that railway companies will seek the most capable men for promotion to the responsible positions, for where such a policy is not followed any plan will fail.

A plan which I would propose would be for railway companies to pick what material they can from among college men who will demonstrate their fitness by taking hold with their hands, and at the same time give equal opportunity to trackmen to qualify as engineers. If bright young men among the track laborers, possessed of a common-school education, were given opportunity to work with the surveying parties and at various kinds of engineering work they would readily pick up the use of instruments, and a little encouragement might induce many of such men to later pursue a college course in engineering. This seems like hitching the horse at the right end of the cart, for then the college graduate is ready and well able to take hold of any position in maintenance work where he can get the opportunity, and he need not then become the subject of ridicule among track laborers. He would also effect a considerable economy in time, both in and out of college, for, knowing methods of work and the practical limitations which have to be met, he would be less inclined to waste time and energy on so many of the hair-splitting niceties and adjustments which originate with inexperienced trackmen. It is a fault with many young engineers that they attempt an undue refinement in applying mathematics to simple track problems.

Why not such a plan? In the transportation department telegraph operators and station agents, with no better fundamental education than some trackmen, have every opportunity for promotion, and for a common thing such men reach the highest positions possible on railroads. To deny trackmen equal opportunities for promotion is to discourage honest effort and drive capable men from the field. If the line of promotion to positions in charge of track was open to engineers exclusively it would not be long, wherever such a policy should become established, until there would be no trackmen worthy of the name. On the other hand if trackmen were encouraged in some such manner as is here recommended there would be some inducement for young men of ambition and energy to remain with the work. There is no getting around the fact that the best prepared candidate for the position of roadmaster, other qualifications aside, is the man able to qualify at least for the duties of a section foreman. It is from a class of men so qualified that the great majority of roadmasters now holding positions have been selected. The most commendable plan would then seem to be to make it a requisite that candidates for the position of roadmaster should have handled track tools for at least two years and be able to qualify as civil engineers. If such a rule were adhered to as rigidly as possible there can be scarcely any doubt that but little time would elapse before eligible candidates would be forthcoming in sufficient numbers to fill all positions for which openings might exist.

Capacity for the performance of executive duties requires knowledge, judgment and decision. Judgment is proper discrimination in the use of knowledge, and decision is courage. General knowledge without particular application under specific conditions is called theory. Practice is the application of judgment to theory, or to general principles, which is only another name for theory. Now general knowledge or theory or general principles, and judgment are acquired by different processes. Knowledge of things and principles may be acquired without seeing the thing or seeing an application of the principle, but judgment on the application of principles and how to establish things in their right relations is rarely if ever acquired except through experience of some sort. Again, knowledge and judgment are different in another respect, in that the former may be more or less a composite of what different men have made known, and may be acquired by an effort of the mind; while judgment is individual, and is the result of one's own habits of thought; and there is nothing which will clarify one's thinking better than experience. The safest judgment is that which is built on its own foundation. The management of affairs is best learned through the management of lesser affairs; and the study of men, especially as related to business affairs, is not a study of books. Technical learning facilitates, but it does not originate. It sets up a standard of what things ought to be, but it does not always point the way for bringing those things about. It does not make up for defects of ability or for incapacity to move things with the facilities at hand. Technical education aims at the ideal, but it requires judgment to deal successfully with realities. In railroading, no more than elsewhere, are ideal conditions the rule. Generally speaking, the most successful railway officer is he who can combine the education which seeks the ideal with that which enables him in any situation to meet the real conditions at hand—in other words he who can combine a technical education with business experience. This, after all, is but a simple matter, easily accomplished if the right kind of men are appointed to positions where they belong and are advanced on their merits.

207. Limit of Capacity of Single Track.—An important question with heavy-traffic single-track roads is the limit of capacity for economical operation. There are so many varying conditions with different roads that theories of train movements in relation to assumed passing points are of but little value except as a rough guide. Exact rules cannot be laid down that will apply to all cases, for the investigation of the matter is largely a special problem for each individual road. Nevertheless, it is evident that there must be certain principles of construction and operation which have a general bearing on the question. When the management of a single-track line is confronted with a congestion of train movements it is seasonable to enquire into the possibilities of relieving the situation, and some of the lines of improvement which may be considered with a view to increase the traffic capacity of the road and put the question of the construction of a second track farther off, are as follows: More passing sidings; extension of siding capacity; a better distribution of sidings; extension or rearrangement of terminal facilities; installation or extension of interlockings or block signals; power units of larger capacity; a more advantageous system of train loading; a better system of train dispatching; a better arrangement of water supply facilities in relation to stations stops, or the making of such facilities accessible to trains while standing on side-track; more systematic attention to locomotive repairs; better discipline; better management, etc. Such matters and perhaps others are of general application, even though they must be considered from different points of view, and a discussion of the question on these lines should bring out valuable information. The issue of the Railway and Engineering Review for March 15, 1902, contained a lengthy symposium on the limit of capacity of single-track roads, consisting of the opinions of 26 railway officials, and the following are brief extracts from these expressions of opinion:

"The problem concerning the capacity of single-track roads is governed by special conditions rather than general principles. Theoretically, this capacity is reached when every passing track is occupied by a train or trains in one direction, meeting with uniform movement at each of these sidings, trains going in the opposite direction. This, of course, is an imaginary condition, and would never be attained in actual practice. The nearest approach to it, with the number of hours required to make the trip, together with the number of trips times the number of cars or tons per train, are data which give the capacity of the road for each 24 hours.

"The capacity is greater on a level road than on a mountainous one. On the level road trains can generally be depended upon to move at a certain speed. On heavy grades one cannot always tell what speed they will make up hill; consequently there will be more delay to opposing trains, and the more numerous the trains the more delay, and the need of double track becomes apparent. At the same time the greater cost of the improvement on a mountain road confronts the officials and deters the building.

"In a general way, the number of trains has more to do with this question than the freight tonnage. For this reason, a low-grade line can be operated as single track with heavier tonnage than would be possible with a heavy-grade line. Stock, perishable freight and merchandise trains must be hurried forward at greater speed than lower classes of freight, and a road having a big percentage of the former class would require double-tracking sooner than one having the same tonnage but consisting of ore, grain, or similar commodities. The speed of the trains also cuts a considerable figure. A few fast mail trains, the speed of which is very much greater than that of anything else on the road, will hasten the necessity for double track, in order to prevent too much delay to slower trains. The more uniform the speed of all trains the larger the movement that can be handled with a given number of passing tracks. Unbalanced traffic has a bearing on the subject, as this condition increases the number of trains for the same number of tons over what they would be if the traffic was balanced.

"The prime factor in double-tracking railways is to expedite the movement of freight, the railway officials of to-day invariably seeing that passenger trains are kept moving, no matter how great the sacrifice to the freight service. Where competition is so great that the speed of freight trains, and prompt movement thereof, becomes a serious factor in getting and maintaining business, it may be better to double-track a road for much less volume of traffic than would be thought necessary where there was no—or very little—competition. Some roads seem to be able to constantly increase a growing business and yet not make as good time with freight as their competitors. I have in mind one road with heavy grades, fairly good power and facilities, that handles about 1500 trains a month over each division of the line that might be said to have reached the limit of its capacity, because at times the trains get over it only after considerable delay and difficulty; yet it seems possible to further increase the capacity of that line by improving its facilities. The capacity and condition of the power on a railroad must also be considered.

"Whether the traffic is fairly well distributed throughout the day and night, or whether it has to be handled during a short space of time is another phase of the question. On a line where the passenger traffic is light and freight traffic heavy and of such nature that it can be distributed throughout the 24 hours, a greater density of traffic may be handled satisfactorily on a single track than otherwise.

"The fact that a single-track road may be blockaded with traffic is not necessarily an indication that it is being worked up to or beyond the limit of economical capacity. The matter really turns upon the question as to whether proper facilities are at hand, and whether train operation in conjunction with these facilities is being properly directed. Ample terminal facilities are necessary, so that trains can be run in large numbers in one direction, meeting in the opposite direction only passenger and perishable freight trains; and if these trains are late, time orders should be given, and not detain them at telegraph offices to give meeting orders; giving passenger and perishable freight trains the preference to insure their making schedule time, letting opposing trains make where they can for them. With a large number of trains bound in opposite directions delays are unavoidable, whereas if they could be run in groups in one direction there would be no delay. Trains would reach terminals on time, motive power would be ready for other trains on time, less consumption of coal and other supplies, less overtime to trainmen, less liability of accidents, etc.

"On roads having a large number of passenger trains, if it can be arranged to have the movement of freight at the time of day when the least number of passenger trains are moving, it will be found that the necessity for double-track arrangements can be postponed for a considerable length of time.

"Train dispatching has largely to do with the volume of business which can be moved over single-track railroads, and actual experience in the matter of what can be accomplished by one set of dispatchers using certain methods, as compared with another set of dispatchers with other practices, is as day and night when compared with results. If too many miscellaneous duties are required of a dispatcher train movements are more than likely to be slighted. This is no theory. His office should not be public. He should not be required to act as operator and deliver orders to trains. It takes time to fix manifold and carbon sheets as well as to fill in all the notations on the order blanks, to say nothing of leaving his desk to deliver them when other trains out on the line may be demanding attention. Under these conditions he is called upon to answer all sorts of questions and engage in conversation, and these interruptions are many times detrimental to the proper performance of his work.

"Side-tracks four to five miles apart are facilities essential to the development of the full capacity of single track. These side-tracks should be long enough to hold at least two trains, and in connection with this feature it is important to have facilities for taking water while the trains wait on side-track. Another important matter is that sidings should preferably be located where it will not be necessary for trains to cut for crossings, as the necessity to do this is a matter of considerable bother and takes time. Lap sidings, with towermen to throw the switches, are also much in favor. The A., B. & C. Ry., for instance, handles a larger regular tonnage than some of the roads in its territory that have double track; yet it still has considerable single track. They have accomplished this by a system of sidings four and five miles apart constructed on the lap plan, with an operator to throw the switches for incoming trains. At each station there are two sidings, many of them of sufficient length to accommodate three 60-car trains.

"I believe that with lap sidings and interlocking towers at each lap, the sidings being located from three to four miles apart, and trains required in all cases to head up to the tower when using the sidings, a single track could be operated more satisfactorily than a double track without siding facilities and where trains are required to cross over to get out of the way of faster trains following. I also believe that such an arrangement of single track, with an absolute block in both directions, as would be entirely feasible, would be safer to operate than a double track not blocked.

"The distribution of side-tracks is governed by special conditions. It is found that on certain parts of roads trains more frequently meet than on other parts, and the modern method of blocking trains makes the need of frequent sidings felt. Where trains frequently meet they should be close together, serving as a basis for sections of double track in the end by joining them together. For heavy volume of business passing tracks should not be more than five miles apart, and for low-grade lines, where heavy tonnage is being handled in the trains, three to four miles will be found much better.

"I think a passing track, of not less than 150-car capacity, should be located every 5 or 6 miles on single track; and in addition, where the traffic is heavier in one direction than in the other, more passing tracks should be located midway between the regular passing tracks, to accommodate the heaviest traffic. The value of a long passing siding can often be increased by the construction of a crossover track midway between the switches, so that if two trains are headed in they can both pull out, whereas without the crossover one is required to back out. Where there is not room for a long passing siding, a second siding can perhaps be constructed outside of and parallel to the first one.

"In the handling of heavy business I greatly favor the double passing track, i. e., one on each side of main line, or side by side, as the case may be, in preference to the long passing track, even where the latter has intermediate switches.

"Passing sidings where there is no telegraph office are sometimes sources of unexpected and serious delays, and there should, if possible, be a telegraph office at all such sidings. They should be located as near the sidings as it is possible to get them. Where they are at a distance too much time is consumed by conductors getting to the office for orders or by the dispatcher sending the operator out to get the train. Something unforeseen is liable to occur at any time, and if the train is lying at or very near the telegraph office, the dispatcher can very soon get it moved to another meeting or passing point.

"Yards at division termini should have a capacity equal to half the entire capacity both ways of the divisions terminating at the point considered, besides the necessary room for switching. Terminal stations should have a capacity equal to the incoming business multiplied by the average time required to place the cars, discharge, reload and place again. Where the facilities are good this can be done in four days, which would make the capacity four times the incoming business, exclusive of the switching room.

"An arrangement deserving careful attention is the double-tracking of the line for one station interval out from terminals, so as to permit trains made up and ready to start, to leave the terminal without waiting for the arrival of some train which may be delayed just long enough to hold the train about ready to start, but not long enough to permit a meeting at the first siding out on the line. This arrangement also helps out where the capacity of the terminal yard tracks is not sufficient to accommodate all in-bound trains that might seek to enter, before out-bound trains can make ready to leave, in which case the in-bound train must take some outlying side-track and wait for the departure of some of the trains from the yard. Water and fuel stations should be so planned as to enable engines to replenish supplies from either main track or sidings, the water cranes being so placed that passenger trains may take water while making station stops.

"The effect of block signals on single track sometimes expedites and sometimes handicaps traffic; yet on some roads block signals have increased the capacity of short divisions of single-track lines.

"I should say that the capacity of single track would depend on the number of preference or passenger trains; second, the limit of time necessary between passing tracks; third, the question of whether it is necessary to block in one or both directions. For instance: On certain divisions of the D., E. & F. Ry., where we have five important passenger trains each way and where we use located stations wholly for passing tracks, and where heavy tonnage trains are handled, necessitating slow speed and an absolute block maintained in both directions, we have found it difficult to get twelve freight trains each way over the road, in addition to passenger trains, without very serious delay to freight traffic; while it has come under my observation that on roads where block signals are not in use and where passing tracks are located with a view to handling heavy traffic, that more than twice this number of trains are handled without serious delay to freight traffic.

"The influence of block signals on this question can be none other than the best. They go a long way towards making single track both safe and profitable. I cannot conceive how a thoroughly modern, properly installed and properly maintained automatic block signal system, or any other block signal system, for that matter, if properly observed by train men, can operate to the detriment of traffic, either on single or double track.

"Where traffic is heavy on a single-track road there should be a tower block system or an interlocking staff system, in order that it should be impossible for more than one train at a time to be between two stations. Or at points where the traffic is not so heavy, a staff system ought to be used, so that the staff or a ticket must be carried between one station and the other.

"I cannot see how block signals can facilitate train movements, and they will reduce the number of train movements on single track in every instance. I have never been in favor of single-track blocking, as I have always been of the opinion that the proper way is to have a positive telegraph block. With this system any block signals between stations would be useless. By using a permissive block, however, I should think that it would not be safe without block signals between stations. My idea of handling trains on a single-track road is: First a positive telegraph block system with sufficient siding capacity at each station; to have all passenger sidings handled by the operator; to have electric automatic station protective signals to indicate the condition of the main track throughout the station and yard limits, where the view is not good.

"It might be considered necessary to double-track a road when the time of getting freight trains over the line was twice as long—caused by meeting trains and allowing superior ones to pass—as it would be were there no trains to contend with whatever.

"A railroad should not be double-tracked until the grades and curves have been reduced to the lowest practicable limit; the roadbed thoroughly ballasted and equipped with 80 to 100-lb. rails; the limit of weight and capacity of power for economical freight train operation supplied; and passing sidings of sufficient length to accommodate two of the longest trains, which sidings should be placed six or seven miles apart and arranged so that they will form part of the second track. Then when the traffic justifies the running of over eighteen trains in each direction daily, or one train every 90 minutes, the second track should be put in, especially if the heavy traffic is regular throughout the year, or for a period of over four months.

"My opinion would be that 50 trains could be handled each way on a division successfully, not to exceed from 100 to 110 miles, where everything is favorable, such as weather, grades not too heavy and long, engines properly rated and in good condition, track in good shape, water tanks at least every 20 miles, good long side-tracks not over 6 miles apart, capable of holding any two of these trains.

"In a general way, my opinion is that a road having 60 trains within 24 hours, even with ample side-track facilities, and an average number of passenger trains, should be considered as requiring double track. Of course, if there are many fast through passenger trains and fast through freight trains it would likely be found advisable to provide double track when the total number of trains reaches 50.

"I have seen cases where a single-track road was capable of handling, under the best conditions, 70 trains a day, ten being passenger. If 25 or 30 were passenger it would change the situation very materially.

"On a road on which I was once employed as dispatcher, we handled in twelve hours, over 13 miles of single track, 70 local passenger trains and from 10 to 15 extra freights, and yet there was but very little delay. There were six sidings—two, each one mile long, and four, each a half mile long, and train order offices at each siding.

"This company is now building some double track where the train density is from fifty to sixty trains per day both ways, but where the traffic is largely composed of live stock which must have quick movement and must move at a certain time of the day, and where the fast freight in the opposite direction moves over the same district at about the same time of day.

"In commencing to double-track a road the work should begin where the largest amount of traffic is handled, which is usually at one of the terminals of the line. But if the volume of traffic is on the middle of the line the double-track work should be begun at this point.

"I would say, in a general way, that double-tracking ought to be done before the limit of capacity for single track is reached, as the work of double-tracking itself involves a large number of additional trains upon the single track, and the double-tracking can be done only at an enormously increased expense if it is postponed until the full capacity of single track has been reached. I have had as many as five or six trains in a district of 20 or 30 miles, held out all day long without a minute's use of main track, and gangs idle in consequence. I would say that in a stretch of 25 miles an increased expense in train service of $50,000 might be caused by postponing double-tracking until the single track was crowded to its fullest capacity with regular trains. In place of about $1000 per mile train service in double-tracking, we have figures running up to $3000 per mile, or somewhat over, the cause being idle time of trains."

208. Hand Cars of the Manitou & Pike's Peak Ry.—The average grade of the cog road from Manitou, Colo., to the top of Pike's Peak is 844.8 ft. per mile, and in several places it is as steep as 25 per cent, or at the rate of 1,320 ft. per mile. In order to insure traction for the locomotives rack bars are laid in the middle of the track, as seen in the illustration on page 703. For rapid transit down grade the officers and employees of this road use what are known as "slide boards," on which they can coast down the track at great speed. The device consists essentially of a plank 12 ins. wide and 3 ft. in length, along the middle of the under side of which there is a cleat which runs between the rack bars and holds the vehicle thereon. On either side of the middle cleat there are brake shoes, bolted to the plank at one end and bearing against the outside surfaces of the rack bars or cog teeth. These brake shoes are applied by clamps bent over the sides of the plank and operated by a lever which, as appears in the illustration, the rider holds within his grasp. The plank bears upon the upper edges of the cog teeth by steel runners, which consist of two straps bent over the ends of the plank. To hold the device in balance a bar or pole is bolted to the top of the plank, crosswise, extending over the track rail on either side. Across the front end of the plank there is bolted a rest for the rider's feet. The weight of the slide board entire is but 35 lbs. The position of the rider when in motion is clearly apparent in the illustration, and the method of operating the device is simply to place it on the track, sit down and attend to the brake. The speed attainable depends upon the pleasure of the rider. A record of a fraction under a mile a minute has been made, and a ride at this speed over the rack rails is said to be stimulating if not exciting. The entire stretch of track from the top of the peak down to Manitou—9 miles—is used, except at four points where the rack rails diverge at sidings. At these points the rider must come to a stop and carry his board about 40 ft. On one occasion an employee of the company made the trip over the 9 miles in 11 minutes. The friction of the runners on the rack rails causes the former to heat, and on the lighter grades of 8 to 12 per cent the heated runners have been known to adhere to the rack rail and stop the vehicle. For the purpose of lubrication, and to prevent the runners from unduly heating, the rider carries a bar of soap which he applies to the top of the rack teeth by reaching over in front of the board. Even then, the friction is so great that, at very high speed, on the long grades, streams of fire follow the flight of the rider.

EXPLANATION OF TABLES.

Table V.—The sine, cosine, tangent, co-tangent, or external secant of an angle greater than 90 degrees is numerically the sine, cosine, etc. of the difference between that angle and 180 degrees.

The versed sine of an angle greater than 90 degrees is equal to 2 minus the versed sine of the difference between that angle and 180 degrees.

Table XI.—The lower frog numbers are inserted in the table for use on street railways.

Tables XIII and XIV.—These tables have been worked out to give measurements for point switch turnouts, having switch points of various lengths, corresponding to different values of spread at the heel. The turnout curve in every case is tangent to the point rail at the heel, and to the frog at the point of frog. For the change in middle ordinate of outside rail of turnout when the main track is curved, see § 68, chapter VI.

Table XIV.—Measurements for Point-Switch Turnouts.

Gage, 4 feet 8½ inches. Spread at Heel, 5½ inches. Figure 140.

Frog No. n	Frog Angle F Deg	Frog Angle F Min	Frog Angle F Sec	Length of Switch p Ft	Switch Angle p Deg	Switch Angle p Min	Switch Angle p Sec	Radius of Turnout Curve R = r — ½g Ft	Degree of Turnout Curve Deg	Degree of Turnout Curve Min	Headblock or Point of Switch to Point of Frog AC+KF Ft	Mid. Ordinate (OM) of Outside Rail, M'n'r'k Straight In.	Quarter Ordinate Main Track Straight In	Middle or Crotch Frog Angle F'. Deg	Middle or Crotch Frog Angle F'. Min	Middle or Crotch Frog Angle F'. Sec	Middle or Crotch Frog No. n".	Headblock or Point of Switch to Point of Middle or Crotch Frog. Ft	Frog No. n
6	9	31	39	15	1	45	04	316.56	18	11	**58.04**	8 13/16	6 19/32	12	58	52	4.39	41.31	**6**
6½	8	47	51	"		"		373.81	15	22	**61.04**	8 17/32	6 13/32	12	01	44	4.75	42.93	**6½**
7	8	10	16	"		"		436.47	13	09	**63.96**	8¼	6 3/16	11	13	04	5.09	44.48	**7**
7½	7	37	41	"		"		504.67	11	22	**66.81**	8	6	10	30	24	5.44	45.98	**7½**
8	7	09	10	"		"		578.60	9	55	**69.58**	7¾	5 13/16	9	54	18	5.77	47.37	**8**
8½	6	43	59	"		"		658.60	8	42	**72.30**	7½	5⅝	9	21	48	6.11	48.74	**8½**
9	6	21	35	"		"		744.97	7	42	**74.94**	7¼	5 7/16	8	53	42	6.43	50.01	**9**
9½	6	01	32	"		"		837.94	6	51	**77.53**	7	5¼	8	27	24	6.76	51.30	**9½**
10	5	43	29	"		"		937.82	6	07	**80.05**	6 25/32	5 3/32	8	04	06	7.09	52.52	**10**
8	7	09	10	18	1	27	33	567.50	10	07	**74.44**	8 7/16	6 11/32	9	48	16	5.83	52.12	**8**
8½	6	43	59	"		"		644.27	8	54	**77.35**	8 7/32	6 5/32	9	15	20	6.18	53.66	**8½**
9	6	21	35	"		"		726.70	7	53	**80.19**	8	6	8	46	32	6.52	55.12	**9**
9½	6	01	32	"		"		814.91	7	02	**82.98**	7 25/32	5 27/32	8	20	30	6.86	56.56	**9½**
10	5	43	29	"		"		909.09	6	18	**85.71**	7 19/32	5 11/16	7	56	12	7.21	58.00	**10**
10½	5	27	09	"		"		1009.50	5	41	**88.38**	7⅜	5 17/32	7	35	54	7.53	59.29	**10½**
11	5	12	18	"		"		1116.33	5	08	**90.99**	7 5/32	5⅜	7	17	12	7.85	60.55	**11**
11½	4	58	45	"		"		1229.72	4	40	**93.56**	6 31/32	5 7/32	6	59	12	8.19	61.84	**11½**
12	4	46	19	"		"		1350.35	4	15	**96.08**	6 25/32	5 3/32	6	43	42	8.51	63.01	**12**
10	5	43	29	20	1	18	47	897.12	6	23	**89.11**	8	6	7	52	48	7.26	61.33	**10**
10½	5	27	09	"		"		994.78	5	46	**91.90**	7 13/16	5 27/32	7	32	24	7.59	62.71	**10½**
11	5	12	18	"		"		1098.38	5	13	**94.63**	7⅝	5 23/32	7	13	42	7.92	64.06	**11**
11½	4	58	45	"		"		1207.98	4	45	**97.31**	7 7/16	5 9/16	6	55	48	8.26	65.44	**11½**
12	4	46	19	"		"		1324.18	4	20	**99.96**	7¼	5 7/16	6	40	12	8.58	66.71	**12**

Table XIII.—Measurements for Point-Switch Turnouts.

Gage of Track, 4 feet 8½ inches. Spread at Heel, 5 inches. Figure 140.

Frog No. n.	Frog Angle F			Length of Switch p	Switch Angle P			Radius of Turnout Curve $R=r-\frac{1}{2}g$	Degree of Turnout Curve.		Headblock or Point of Switch to Point of Frog AC+KF	Mid. Ordinate (ON) of Outside Rail, M'n Tr'k Straight	Quarter Ordinate. Main Track Straight.	Middle or Crotch Frog Angle F''.			Middle or Crotch Frog No. n''.	Headblock or Point of Switch to Point of Middle or Crotch Frog.	Frog No. n.
	Deg	Min	Sec	Ft	Deg	Min	Sec	Ft	Deg	Min	Ft	In	In	Deg	Min	Sec		Ft	
4	14	15	00	12	1	59	23	139.92	41	53	**42.08**	9¾	7 5/16	19	21	12	2.93	30.97	**4**
4½	12	40	49	"		"		178.07	32	37	**45.34**	9 7/16	7 1/16	17	16	30	3.29	32.83	**4½**
5	11	25	16	15	1	35	30	218.69	26	26	**52.63**	9¾	7 5/16	15	31	00	3.67	38.69	**5**
5½	10	23	20	"		"		265.75	21	41	**55.90**	9 15/32	7 3/32	14	09	20	4.03	40.56	**5½**
6	9	31	39	"		"		317.72	18	07	**59.09**	9 7/32	6 29/32	13	00	40	4.38	42.37	**6**
6½	8	47	51	"		"		374.80	15	20	**62.21**	8 15/16	6 11/16	12	02	40	4.74	44.12	**6½**
7	8	10	16	"		"		437.11	13	08	**65.25**	8 11/16	6 17/32	11	13	20	5.09	45.78	**7**
7½	7	37	41	"		"		504.75	11	22	**68.23**	8 7/16	6 5/16	10	30	30	5.44	47.39	**7½**
8	7	09	10	"		"		577.88	9	56	**71.13**	8 3/16	6⅛	9	54	00	5.77	48.90	**8**
8½	6	43	59	"		"		656.80	8	44	**73.97**	7 31/32	5 31/32	9	21	00	6.11	50.39	**8½**
9	6	21	35	"		"		741.72	7	44	**76.75**	7 23/32	5 25/32	8	53	00	6.44	51.77	**9**
9½	6	01	32	"		"		832.82	6	53	**79.47**	7½	5⅝	8	26	00	6.78	53.19	**9½**
10	5	43	29	"		"		930.35	6	10	**82.13**	7 9/32	5 15/32	8	02	00	7.12	54.56	**10**

Table XI.—Measurements for Stub-Switch Turnouts.

Gage of Track, 4 feet 8½ inches. Figures 67 and 168.

Frog No. n	Frog Angle F		Turnout Radius R	Degree of Turnout Curve.		For 5-in. Throw: Headblock to Point of Frog. D F	For 5-in. Throw: Length of Stub Switch Rail. A B	Point of Frog to Heel of Switch. C F	For 5½-in. Throw: Headblock to Point of Frog. D F	For 5½-in. Throw: Length of Stub Switch Rail. A B	Middle ordinate of Outside Rail Main Track Straight. O M	Quar. ordin'te Main Track straight O'M'	Change in Mid. Ordin'te per Deg. of Curve of Main Track	Change in Quar. Ordin'te per Deg. of Curve of Main Track	Middle or Crotch Frog No. n''.	Angle of Middle or Crotch Frog F''.		Head Block to Point of Middle or Crotch Frog K F''.	Frog No. n
	Deg	Min	Ft	Deg	Min	Ft	Ft	Ft	Ft	Ft	In	In	In	In		Deg	Min	Ft	
4	14	15	150.66	38	46	**26.45**	11.21	37.66	**25.91**	11.75	14 5/32	10⅝	0[illegible]	0[illegible]	2.82	20	08	15.53	**4**
4½	12	41	190.67	30	24	**29.76**	12.61	42.37	**29.15**	13.22	14 5/32	10⅝	0[illegible]	0[illegible]	3.17	17	55	17.44	**4½**
5	11	25	235.40	24	32	**33.07**	14.01	47.08	**32.39**	14.69	14 5/32	10⅝	0[illegible]	0[illegible]	3.53	16	08	19.36	**5**
5½	10	23	284.83	20	13	**36.38**	15.41	51.79	**35.63**	16.16	14 5/32	10⅝	0[illegible]	0[illegible]	3.88	14	41	21.28	**5½**
6	9	32	338.98	16	58	**39.69**	16.81	56.50	**38.87**	17.63	14 5/32	10⅝	0[illegible]	0[illegible]	4.24	13	28	23.20	**6**
6½	8	48	397.83	14	26	**42.99**	18.21	61.20	**42.11**	19.09	14 5/32	10⅝	0[illegible]	0[illegible]	4.59	12	26	25.13	**6½**
7	8	10	461.38	12	27	**46.29**	19.62	65.91	**45.35**	20.56	14 5/32	10⅝	1[illegible]	0[illegible]	4.94	11	33	27.05	**7**
7½	7	38	529.65	10	50	**49.60**	21.02	70.62	**48.59**	22.03	14⅛	10[illegible]	1[illegible]	0[illegible]	5.30	10	47	28.97	**7½**
8	7	09	602.62	9	31	**52.91**	22.42	75.33	**51.83**	23.50	14⅛	10[illegible]	1[illegible]	1[illegible]	5.65	10	07	30.90	**8**
8½	6	44	680.31	8	26	**56.22**	23.82	80.04	**55.07**	24.97	14⅛	10[illegible]	1[illegible]	1[illegible]	6.01	9	31	32.82	**8½**
9	6	22	762.70	7	31	**59.52**	25.22	84.74	**58.30**	26.44	14⅛	10[illegible]	1[illegible]	1[illegible]	6.36	9	00	34.75	**9**
9½	6	02	849.79	6	45	**62.83**	26.62	89.45	**61.54**	27.91	14⅛	10[illegible]	2[illegible]	1[illegible]	6.71	8	31	36.67	**9½**
10	5	43	941.60	6	05	**66.14**	28.02	94.16	**64.78**	29.38	14⅛	10[illegible]	2[illegible]	1[illegible]	7.07	8	06	38.60	**10**
10½	5	27	1038.11	5	31	**69.45**	29.42	98.87	**68.02**	30.85	14⅛	10[illegible]	2[illegible]	1[illegible]	7.42	7	43	40.53	**10½**
11	5	12	1139.34	5	02	**72.76**	30.82	103.58	**71.26**	32.32	14⅛	10[illegible]	2[illegible]	2[illegible]	7.77	7	22	42.45	**11**
11½	4	59	1245.27	4	36	**76.05**	32.23	108.28	**74.49**	33.79	14⅛	10[illegible]	3[illegible]	2[illegible]	8.13	7	02	44.38	**11½**
12	4	46	1355.00	4	14	**79.36**	33.63	112.99	**77.73**	35.26	14⅛	10[illegible]	3[illegible]	2[illegible]	8.48	6	45	46.30	**12**

Table XVI.—Direct Distances Between Frogs on Ladder Tracks.

Distances AB, BC, etc., in Figure 212.

Frog No.	Distances between Track Centers.											Frog No.
	10	**10.5**	**11**	**11.5**	**12**	**12.5**	**13**	**13.5**	**14**	**14.5**	**15**	
4	40.62	42.66	44.69	46.72	48.75	50.78	52.81	54.84	56.87	58.91	60.94	**4**
4½	45.56	47.83	50.11	52.39	54.67	56.94	59.22	61.50	63.78	66.06	68.33	**4½**
5	50.50	53.02	55.55	58.07	60.60	63.12	65.65	68.17	70.70	73.22	75.75	**5**
5½	55.45	58.23	61.00	63.77	66.54	69.32	72.09	74.86	77.64	80.41	83.18	**5½**
6	60.41	63.44	66.46	69.48	72.50	75.52	78.54	81.56	84.58	87.60	90.62	**6**
6½	65.38	68.65	71.92	75.19	78.46	81.73	85.00	88.27	91.54	94.81	98.08	**6½**
7	70.31	73.88	77.39	80.91	84.43	87.95	91.47	94.98	98.50	102.02	105.54	**7**
7½	75.33	79.10	82.87	86.63	90.40	94.17	97.93	101.70	105.47	109.23	113.00	**7½**
8	80.31	84.33	88.34	92.36	96.37	100.39	104.40	108.42	112.44	116.45	120.47	**8**
8½	85.29	89.56	93.82	98.09	102.35	106.61	110.88	115.14	119.41	123.67	127.94	**8½**
9	90.28	94.79	99.30	103.82	108.33	112.85	117.36	121.87	126.39	130.90	135.41	**9**
9½	95.26	100.03	104.79	109.55	114.32	119.08	123.84	128.61	133.37	138.13	142.89	**9½**
10	100.25	105.26	110.28	115.29	120.30	125.31	130.33	135.34	140.35	145.36	150.38	**10**
10½	105.24	110.50	115.76	121.03	126.29	131.55	136.81	142.07	147.34	152.60	157.86	**10½**
11	110.23	115.74	121.25	126.76	132.28	137.79	143.30	148.81	154.32	159.83	165.34	**11**
11½	115.22	120.98	126.74	132.50	138.26	144.02	149.78	155.54	161.30	167.06	172.82	**11½**
12	120.21	126.22	132.23	138.24	144.25	150.26	156.27	162.28	168.29	174.30	180.31	**12**

Table V.—Natural Sines, Cosines, Tangents, Etc.

Deg.	Min.	Sine.	Cosine.	Tangent.	Cotangent.	Ver. Sine.	Ex. Secant.	Deg.	Min.
0		.00000	1.00000	.00000	Infinite.	.00000	.00000	0	
0	30	.00873	.99996	.00873	114.589	.00004	.00004	0	30
1		.01745	99985	.01746	57.2900	00015	.00015	1	
1	30	.02618	.99966	.02619	38.1885	.00034	.00034	1	30
2		.03490	.99939	.03492	28.6363	.00061	.00061	2	
2	30	.04362	.99905	.04366	22.9038	.00095	.00095	2	30
3		.05234	.99863	.05241	19.0811	.00137	.00137	3	
3	30	.06105	.99813	.06116	16.3499	.00187	.00187	3	30
4		.06976	.99756	06993	14.3007	.00244	.00244	4	
4	30	.07846	.99692	.07870	12.7062	.00308	.00309	4	30
5		**.08716**	**.99619**	**.08749**	**11.4301**	**.00381**	**.00382**	**5**	
5	30	.09585	.99540	.09629	10.3854	.00460	.00463	5	30
6		.10453	.99452	.10510	9.51436	.00548	.00551	6	
6	30	.11320	.99357	.11394	8.77689	.00643	.00647	6	30
7		.12187	.99255	.12278	8.14435	.00745	.00751	7	
7	30	.13053	.99144	.13165	7.59575	.00856	.00863	7	30
8		.13917	.99027	.14054	7.11537	.00973	.00983	8	
8	30	.14781	.98902	.14945	6.69116	.01098	.01111	8	30
9		.15643	.98769	.15838	6.31375	.01231	.01247	9	
9	30	.16505	.98629	.16734	5.97576	.01371	.01391	9	30
10		**.17365**	**.98481**	**.17633**	**5.67128**	**.01519**	**.01543**	**10**	
10	30	.18224	.98325	.18534	5.39552	.01675	.01703	10	30
11		.19081	.98163	.19438	5.14455	.01837	.01872	11	
11	30	.19937	.97992	.20345	4.91516	.02008	.02049	11	30
12		.20791	.97815	.21256	4.70463	.02185	.02234	12	
12	30	21644	.97630	.22169	4.51071	.02370	.02428	12	30
13		.22495	.97437	.23087	4.33148	.02563	.02630	13	
13	30	.23345	.97237	.24008	4.16530	.02763	.02842	13	30
14		.24192	.97030	.24933	4.01078	.02970	.03061	14	
14	30	.25038	.96815	.25862	3.86671	.03185	.03290	14	30
15		**.25882**	**.96593**	**.26795**	**3.73205**	**.03407**	**.03528**	**15**	
15	30	.26724	.96363	.27732	3.60588	.03637	.03774	15	30
16		.27564	.96126	.28675	3.48741	.03874	.04030	16	
16	30	.28402	.95882	.29621	3.37594	.04118	.04295	16	30
17		.29237	.95630	.30573	3.27085	.04370	.04569	17	
17	30	.30071	.95372	.31530	3.17159	.04628	.04853	17	30
18		.30902	.95106	.32492	3.07768	.04894	.05146	18	
18	30	.31730	.94832	.33460	2.98868	.05168	.05449	18	30
19		.32557	.94552	.34433	2.90421	.05448	.05762	19	
19	30	.33381	.94264	.35412	2.82391	.05736	.06085	19	30
20		**.34202**	**.93969**	**.36397**	**2.74748**	**.06031**	**.06418**	**20**	
20	30	.35021	.93667	.37388	2.67462	.06333	.06761	20	30
21		.35837	.93358	.38386	2.60509	.06642	.07115	21	
21	30	.36650	.93042	.39391	2.53865	.06958	.07479	21	30
22		.37461	.92718	.40403	2.47509	.07282	.07853	22	
22	30	.38268	.92388	.41421	2.41421	.07612	.08239	22	30
23		.39073	.92050	.42447	2.35585	.07950	.08636	23	
23	30	.39875	.91706	.43481	2.29984	.08294	.09044	23	30
24		.40674	.91355	.44523	2.24604	.08645	.09464	24	
24	30	.41469	.90996	.45573	2.19430	.09004	.09895	24	30
25		**.42262**	**.90631**	**.46631**	**2.14451**	**.09369**	**.10338**	**25**	
25	30	.43051	.90259	.47698	2.09654	.09741	.10793	25	30
26		.43837	.89879	.48773	2.05030	.10121	.11260	26	
26	30	.44620	.89493	.49858	2.00569	.10507	.11740	26	30
27		.45399	.89101	.50953	1.96261	.10899	.12233	27	
27	30	.46175	.88701	.52057	1.92098	.11299	.12738	27	30
28		.46947	.88295	.53171	1.88073	.11705	.13257	28	
28	30	.47716	.87882	.54296	1.84177	.12118	.13789	28	30
29		.48481	.87462	.55431	1.80405	.12538	.14335	29	
29	30	.49242	.87036	.56577	1.76749	.12964	.14896	29	30
30		**.50000**	**.86603**	**.57735**	**1.73205**	**.13397**	**.15470**	**30**	
30	30	.50754	.86163	.58905	1.69766	.13837	.16059	30	30
31		.51504	.85717	.60086	1.66428	.14283	.16663	31	
31	30	.52250	.85264	.61280	1.63185	.14736	.17283	31	30
32		.52992	.84805	.62487	1.60033	.15195	.17918	32	
32	30	.53730	.84339	.63707	1.56969	.15661	.18569	32	30
33		.54464	.83867	.64941	1.53986	.16133	.19236	33	
33	30	.55194	.83389	.66189	1.51084	.16611	.19920	33	30
34		.55919	.82904	.67451	1.48256	.17096	.20622	34	
34	30	.56641	.82413	.68728	1.45501	.17587	.21341	34	30
35		**.57358**	**.81915**	**.70021**	**1.42815**	**.18085**	**.22077**	**35**	
35	30	.58070	.81412	.71329	1.40195	.18588	.22833	35	30
36		.58779	.80902	.72654	1.37638	.19098	.23607	36	
36	30	.59482	.80386	.73996	1.35142	.19614	.24400	36	30
37		.60182	.79864	.75355	1.32704	.20136	.25214	37	
37	30	.60876	.79335	.76733	1.30323	.20665	.26047	37	30
38		.61566	.78801	.78129	1.27994	.21199	.26902	38	
38	30	.62251	.78261	.79544	1.25717	.21739	.27778	38	30
39		.62932	.77715	.80978	1.23490	.22285	.28676	39	
39	30	.63608	.77162	.82434	1.21310	.22838	.29597	39	30
40		**.64279**	**.76604**	**.83910**	**1.19175**	**.23396**	**.30541**	**40**	
40	30	.64945	.76041	.85408	1.17085	.23959	.31509	40	30
41		.65606	.75471	.86929	1.15037	.24529	.32501	41	
41	30	.66262	.74896	.88473	1.13029	.25104	.33519	41	30
42		.66913	.74314	.90040	1.11061	.25686	.34563	42	
42	30	.67559	.73728	.91633	1.09131	.26272	.35634	42	30
43		.68200	.73135	.93252	1.07237	.26865	.36733	43	
43	30	.68835	.72537	.94896	1.05378	.27463	.37860	43	30
44		.69466	.71934	.96569	1.03553	.28066	.39016	44	
44	30	.70091	.71325	.98270	1.01761	.28675	.40203	44	30
45		**.70711**	**.70711**	**1.00000**	**1.00000**	**.29289**	**.41421**	**45**	
Deg.	Min.	Sine.	Cosine.	Tangent.	Cotangent.	Ver. Sine.	Ex. Secant.	Deg.	Min.

Table V, Continued.

Deg.	Min.	Sine.	Cosine.	Tangent.	Cotangent.	Ver. Sine.	Ex. Secant.	Deg.	Min.
45		**.70711**	**.70711**	**1.00000**	**1.00000**	**.29289**	**.41421**	**45**	
45	30	.71325	.70091	1.01761	.98270	.29909	.42672	45	30
46		.71934	.69466	1.03553	.96569	.30534	.43956	46	
46	30	.72537	.68835	1.05378	.94896	.31165	.45274	46	30
47		.73135	.68200	1.07237	.93252	.31800	.46628	47	
47	30	.73728	.67559	1.09131	.91633	.32441	.48019	47	30
48		.74314	.66913	1.11061	.90040	.33087	.49448	48	
48	30	.74896	.66262	1.13029	.88473	.33738	.50916	48	30
49		.75471	.65606	1.15037	.86929	.34394	.52425	49	
49	30	.76041	.64945	1.17085	.85408	.35055	.53977	49	30
50		**.76604**	**.64279**	**1.19175**	**.83910**	**.35721**	**.55572**	**50**	
50	30	.77162	.63608	1.21310	.82434	.36392	.57213	50	30
51		.77715	.62932	1.23490	.80978	.37068	.58902	51	
51	30	.78261	.62251	1.25717	.79544	.37749	.60639	51	30
52		.78801	.61566	1.27994	.78129	.38434	.62427	52	
52	30	.79335	.60876	1.30323	.76733	.39124	.64268	52	30
53		.79864	.60182	1.32704	.75355	.39819	.66164	53	
53	30	.80386	.59482	1.35142	.73996	.40518	.68117	53	30
54		.80902	.58779	1.37638	.72654	.41221	.70130	54	
54	30	.81412	.58070	1.40195	.71329	.41930	.72205	54	30
55		**.81915**	**.57358**	**1.42815**	**.70021**	**.42642**	**.74345**	**55**	
55	30	.82413	.56641	1.45501	.68728	.43359	.76552	55	30
56		.82904	.55919	1.48256	.67451	.44081	.78829	56	
56	30	.83389	.55194	1.51084	.66189	.44806	.81180	56	30
57		.83867	.54464	1.53986	.64941	.45536	.83608	57	
57	30	.84339	.53730	1.56969	.63707	.46270	.86116	57	30
58		.84805	.52992	1.60033	.62487	.47008	.88708	58	
58	30	.85264	.52250	1.63185	.61280	.47750	.91388	58	30
59		.85717	.51504	1.66428	.60086	.48496	.94160	59	
59	30	.86163	.50754	1.69766	.58905	.49246	.97029	59	30
60		**.86603**	**.50000**	**1.73205**	**.57735**	**.50000**	**1.00000**	**60**	
60	30	.87036	.49242	1.76749	.56577	.50758	1.03077	60	30
61		.87462	.48481	1.80405	.55431	.51519	1.06267	61	
61	30	.87882	.47716	1.84177	.54296	.52284	1.09574	61	30
62		.88295	.46947	1.88073	.53171	.53053	1.13005	62	
62	30	.88701	.46175	1.92098	.52057	.53825	1.16568	62	30
63		.89101	.45399	1.96261	.50953	.54601	1.20269	63	
63	30	.89493	.44620	2.00569	.49858	.55380	1.24116	63	30
64		.89879	.43837	2.05030	.48773	.56163	1.28117	64	
64	30	.90259	.43051	2.09654	.47698	.56949	1.32282	64	30
65		**.90631**	**.42262**	**2.14451**	**.46631**	**.57738**	**1.36620**	**65**	
65	30	.90996	.41469	2.19430	.45573	.58531	1.41142	65	30
66		.91355	.40674	2.24604	.44523	.59326	1.45859	66	
66	30	.91706	.39875	2.29984	.43481	.60125	1.50784	66	30
67		.92050	.39073	2.35585	.42447	.60927	1.55930	67	
67	30	.92388	.38268	2.41421	.41421	.61732	1.61313	67	30
68		.92718	.37461	2.47509	.40403	.62539	1.66947	68	
68	30	.93042	.36650	2.53865	.39391	.63350	1.72850	68	30
69		.93358	.35837	2.60509	38386	.64163	1.79043	69	
69	30	.93667	.35021	2.67462	.37388	.64979	1.85545	69	30
70		**.93969**	**.34202**	**2.74748**	**.36397**	**.65798**	**1.92380**	**70**	
70	30	.94264	.33381	2.82391	.35412	.66619	1.99574	70	30
71		.94552	.32557	2.90421	.34433	.67443	2.07155	71	
71	30	.94832	.31730	2.98868	.33460	.68270	2.15155	71	30
72		.95106	.30902	3.07768	.32492	.69098	2.23607	72	
72	30	.95372	.30071	3.17159	.31530	.69929	2.32551	72	30
73		.95630	.29237	3.27085	.30573	.70763	2.42030	73	
73	30	.95882	.28402	3.37594	.29621	.71598	2.52094	73	30
74		.96126	.27564	3.48741	.28675	.72436	2.62796	74	
74	30	.96363	.26724	3.60588	.27732	.73276	2.74198	74	30
75		**.96593**	**.25882**	**3.73205**	**.26795**	**.74118**	**2.86370**	**75**	
75	30	.96815	.25038	3.86671	.25862	.74962	2.99393	75	30
76		.97030	.24192	4.01078	.24933	.75808	3.13357	76	
76	30	.97237	.23345	4.16530	.24008	.76655	3.28366	76	30
77		.97437	.22495	4.33148	.23087	.77505	3.44541	77	
77	30	.97630	.21644	4.51071	.22169	.78356	3.62023	77	30
78		.97815	.20791	4.70463	.21256	.79209	3.80973	78	
78	30	.97992	.19937	4.91516	.20345	.80063	4.01585	78	30
79		.98163	.19081	5.14455	.19438	.80919	4.24084	79	
79	30	.98325	.18224	5.39552	.18534	.81776	4.48740	79	30
80		**.98481**	**.17365**	**5.67128**	**.17633**	**.82635**	**4.75877**	**80**	
80	30	.98629	.16505	5.97576	.16734	.83495	5.05886	80	30
81		.98769	.15643	6.31375	.15838	.84357	5.39245	81	
81	30	.98902	.14781	6.69116	.14945	.85219	5.76547	81	30
82		.99027	.13917	7.11537	.14054	.86083	6.18530	82	
82	30	.99144	.13053	7.59575	.13165	.86947	6.66130	82	30
83		.99255	.12187	8.14435	.12278	.87813	7.20551	83	
83	30	.99357	.11320	8.77689	.11394	.88680	7.83367	83	30
84		.99452	.10453	9.51436	.10510	.89547	8.56677	84	
84	30	.99540	.09585	10.3854	.09629	.90415	9.43343	84	30
85		**.99619**	**.08716**	**11.4301**	**.08749**	**.91284**	**10.47371**	**85**	
85	30	.99692	.07846	12.7062	.07870	.92154	11.74550	85	30
86		.99756	.06976	14.3007	.06993	.93024	13.33559	86	
86	30	.99813	.06105	16.3499	.06116	.93895	15.38041	86	30
87		.99863	.05234	19.0811	.05241	.94766	18.10732	87	
87	30	.99905	.04362	22.9038	.04366	.95638	21.92559	87	30
88		.99939	.03490	28.6363	.03492	.96510	27.65371	88	
88	30	.99966	.02618	38.1885	.02619	.97382	37.20155	88	30
89		.99985	.01745	57.2900	.01746	.98255	56.29869	89	
89	30	.99996	.00873	114.589	.00873	.99127	113.5930	89	30
90		**1.00000**	**.00000**	Infinite	**.00000**	**1.00000**	Infinite.	**90**	
Deg.	Min.	Sine.	Cosine.	Tangent.	Cotangent.	Ver. Sine.	Ex. Secant.	Deg.	Min.

Table XV.—Distances Between Points of Frogs in Crossovers.

AB (Fig. 182) = Parallel Distance Measured along Main Track.
AC " " = Diagonal Distance direct between Frog Points.
AH " " = Length of Straight Track between Frog Points.

Gage = 4 feet 8½ inches.

Distance between Track Centers.

Frog No.	10			10.5			11			11.5			12		
	AB	AC	AH	AB	AC	AH	AB	AC	AH	AB	AC	AH	AB	AC	AH
4	1.71	5.56	2.96	3.68	6.86	4.99	5.65	8.45	7.02	7.61	10.20	9.05	9.58	12.04	11.08
4½	2.07	5.68	3.18	4.29	7.21	5.46	6.51	9.06	7.74	8.74	11.06	10.01	10.96	13.16	12.29
5	2.42	5.82	3.42	4.89	7.58	5.94	7.37	9.69	8.47	9.84	11.96	10.99	12.32	14.31	13.52
5½	2.75	5.96	3.66	5.48	7.97	6.44	8.21	10.34	9.21	10.93	12.87	11.98	13.66	15.49	14.75
6	3.08	6.12	3.92	6.06	8.38	6.94	9.04	11.01	9.96	12.02	13.81	12.98	15.00	16.68	16.00
6½	3.41	6.29	4.18	6.64	8.81	7.44	9.87	11.70	10.71	13.10	14.75	13.98	16.33	17.88	17.25
7	3.73	6.47	4.44	7.21	9.25	7.96	10.69	12.40	11.48	14.17	15.72	14.99	17.66	19.10	18.51
7½	4.04	6.66	4.71	7.77	9.69	8.47	11.51	13.12	12.24	15.24	16.69	16.01	18.97	20.33	19.77
8	4.35	6.85	4.98	8.34	10.15	8.99	12.32	13.84	13.01	16.31	17.66	17.03	20.29	21.56	21.04
8½	4.66	7.05	5.25	8.90	10.62	9.52	13.13	14.56	13.78	17.37	18.65	18.05	21.60	22.80	22.31
9	4.97	7.26	5.53	9.46	11.09	10.04	13.94	15.30	14.55	18.43	19.64	19.07	22.92	24.05	23.58
9½	5.28	7.47	5.80	10.02	11.57	10.57	14.75	16.04	15.33	19.49	20.64	20.09	24.23	25.30	24.86
10	5.58	7.69	6.08	10.57	12.05	11.10	15.56	16.78	16.11	20.55	21.64	21.12	25.53	26.55	26.13
10½	5.89	7.92	6.36	11.12	12.54	11.62	16.36	17.53	16.89	21.60	22.64	22.15	26.84	27.81	27.41
11	6.19	8.14	6.64	11.68	13.04	12.16	17.17	18.28	17.67	22.66	23.65	23.18	28.14	29.07	28.69
11½	6.49	8.37	6.93	12.23	13.53	12.69	17.97	19.04	18.45	23.71	24.66	24.21	29.45	30.34	29.97
12	6.79	8.61	7.21	12.78	14.03	13.22	18.77	19.80	19.23	24.76	25.67	25.24	30.75	31.60	31.25

12.5			13			13.5			14			14.5			15			Frog No.
AB	AC	AH	AB	AC	AH	AB	AC	AH	AB	AC	AH	AB	AC	AH	AB	AC	AH	
11.55	13.93	13.11	13.52	15.86	15.15	15.49	17.81	17.18	17.46	19.78	19.21	19.43	21.75	21.24	21.40	23.74	23.27	4
13.18	15.31	14.57	15.40	17.49	16.85	17.62	19.70	19.12	19.85	21.91	21.40	22.07	24.14	23.68	24.29	26.38	25.96	4½
14.79	16.72	16.04	17.27	19.15	18.57	19.74	21.61	21.09	22.22	24.08	23.62	24.69	26.56	26.14	27.17	29.05	28.67	5
16.39	18.15	17.53	19.12	20.84	20.30	21.84	23.55	23.07	24.57	26.27	25.84	27.30	29.00	28 62	30.03	31.74	31.39	5½
17.98	19.59	19.02	20.96	22.54	22.04	23.94	25.50	25.06	26.92	28.47	28.08	29.90	31.46	31.10	32.87	34.45	34.12	6
19.56	21.05	20.52	22.79	24.25	23.79	26.02	27.47	27.06	29.25	30.69	30.33	32.48	33.93	33.60	35.71	37.17	36.87	6½
21.14	22.53	22.03	24.62	25.98	25.55	28.10	29.44	29.07	31.58	32.92	32.58	35.07	36.41	36.10	38.55	39.90	39.62	7
22.71	24.01	23.54	26.44	27.71	27.31	30.17	31.43	31.07	33.91	35.16	34.84	37.64	38.89	38.61	41.38	42.64	42.38	7½
24.28	25.50	25.06	28.26	29.45	29.07	32.24	33.42	33.09	36.23	37.40	37.10	40.21	41.39	41.12	44.20	45.38	45.13	8
25.84	26.99	26.58	30.08	31.20	30.84	34.31	35.42	35.10	38.55	39.65	39.37	42.78	43.89	43.63	47.02	48.13	47.90	8½
27.40	28.49	28.10	31.89	32.95	32.61	36.37	37.42	37.12	40.86	41.90	41.64	45.35	46.39	46.15	49.83	50.88	50.67	9
28.96	29.99	29.62	33.70	34.70	34.38	38.44	39.43	39.15	43.17	44.16	43.91	47.91	48.90	48.67	52.65	53.64	53.44	9½
30.52	31.50	31.15	35.51	36.46	36.16	40.50	41.44	41.17	45.48	46.42	46.18	50.47	51.41	51.20	55.46	56.41	56.21	10
32.08	33.01	32.67	37.32	38.23	37.93	42.55	43.45	43.20	47.79	48.69	48.46	53.03	53.93	53.72	58.27	59.17	58.98	10½
33.63	34.52	34.20	39.12	39.99	39.71	44.61	45.47	45.22	50.10	50.95	50.74	55.59	56.44	56.25	61.08	61.94	61.76	11
35.19	36.04	35.73	40.93	41.76	41.49	46.66	47.49	47.25	52.40	53.22	53.01	58.14	58.96	58.77	63.88	64.71	64.53	11½
36.74	37.56	37.26	42.73	43.53	43.27	48.72	49.51	49.28	54.71	55.49	55.29	60.70	61.48	61.30	66.69	67.48	67.31	12

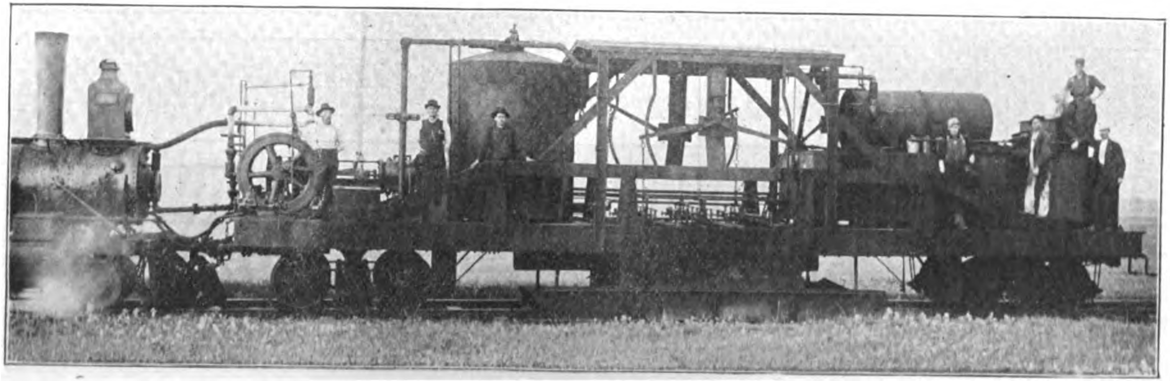


Fig. 537—Weed-Burning Car, Chicago, Milwaukee & St. Paul Ry.

209. Weed-Burning Cars, C., M. & St. P. Ry.—The use of weed-burning machines for destroying vegetation in track is now so well established on roads in the Mississippi Valley that they are no longer regarded as experimental. The Chicago, Milwaukee & St. Paul Ry. is operating machines of more recent design than those described and illustrated in Sec. 90. On the dirt-ballasted track of the various lines of the system in South Dakota, Western Minnesota, and Northwest Iowa, weeds and grass grow all over the roadbed quite vigorously, and the expense of clearing the track by grubbing this vegetation with a shovel or hoe would be a large item.

The car, with all of its appurtenances, is entirely of steel or metal construction. It is 47 ft. long, and the weight, with the tanks empty, is 57½ tons. The "fire pit" is 9 ft. square, reaching 6 ins. beyond the ends of the ties, and is carried under the middle of the car (Fig. 537). Over one of the trucks there is a water tank of 2,500 gals. capacity, surmounted by the main air reservoir, holding air at 70 lbs. pressure. Near the other end of the car there is a cylindrical oil tank with a capacity of 35 bbls., and at the end of the car there is an air compressor taking steam by flexible pipe connection with the locomotive. The water on this car is carried both as a measure

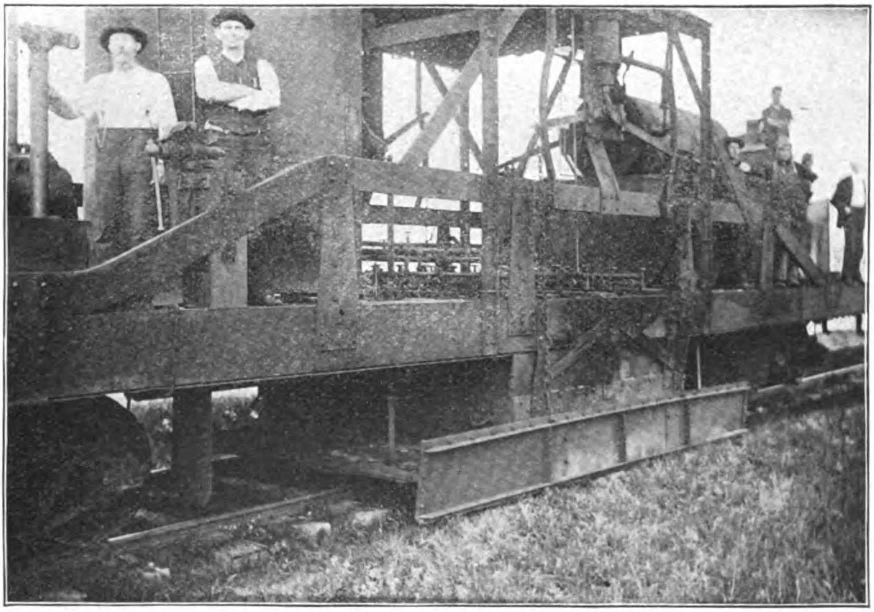


Fig. 538—Near View of Weed-Burning Car, Showing Fire Pit.

of fire protection and for the supply of the locomotive in case the water in the tender should run short. The fire pit consists of a cast iron plate or "floor" 1 in. thick, suspended 17 ins. above the rail, with fire brick 6 ins. thick bolted to its under side, and twenty-five 3-in. combustion chambers or "burners" running vertically through the fire brick and opening downward. The burners are distributed six outside each rail, and 13 between the rails, in rows, staggered. To retain the heat there are side wings (Fig. 538) let down and supported by chains; and there are dampers at each end of the fire pit. The crude petroleum fuel oil is taken from the supply tank and passed through a curled-hair strainer, and then heated to a boiling temperature by coils of steam pipe. It is sprayed into the burners by compressed air at 20 lbs. pressure. To protect the heated fire brick from rain there is a roof over the center of the car. The auxiliary equipment includes a duplex oil pump, for pumping oil out of the supply car hauled with the train. By this means the supply of oil in the service tank can be maintained without interruption while the outfit is in motion. There is also a water pump for fire protection or for filling the water tank through a hose dropped into a stream, as the necessity for taking water in this way frequently arises when the supply runs short and the train is a long distance from a water station. The exhaust from the air compressor is run to the smoke stack of the locomotive and provides sufficient draft without putting on the blower.

When burning weeds, the oil is sprayed into the burners and the flame spreads over the track, underneath the highly heated fire brick. In dry weather the speed of operation is about four miles per hour, but in wet weather the progress is slower. In order to clear the track satisfactorily the car is run over it two trips at each burning. During the first trip the green vegetation is wilted and killed, and after being permitted to dry out for two or three days in the sun the car is again run over the track and the scorched weeds and grass are entirely consumed. There is no trouble from the fire except with rotten or "punky" ties, and as a means of sure protection in this respect a section crew follows the burning outfit to throw dirt upon and extinguish such fires as may become started. The quantity of oil used is about ½ bbl. per mile, and the expense of burning is $1.35 to $1.50 per mile, according to the conditions of vegetable growth and of the weather. These figures cover the entire expense for materials, labor and locomotive attendance. In the part of the country referred to it is necessary to burn over the track three times each season, at intervals of six weeks. The third burning is done partly with a view to kill and consume vegetation which would otherwise catch drifting snow and make trouble in winter.

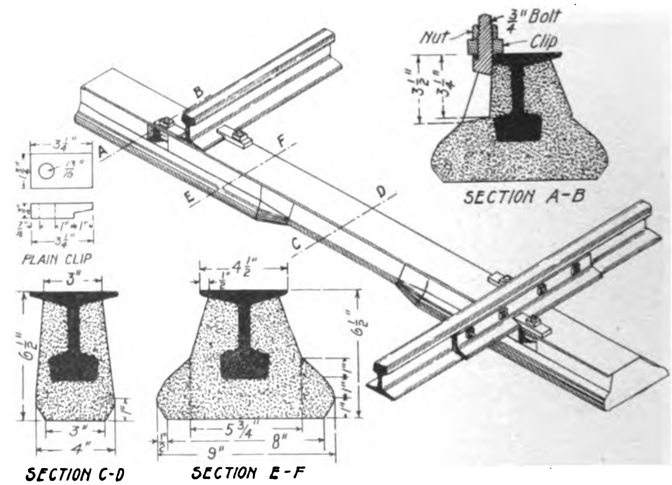


Fig. 539—Construction Details of the Buhrer Concrete-Steel Tie.

The crew required consists of a conductor, who has immediate charge of the machine, two assistants, an engineer and a fireman. The burner car is run either ahead or behind the locomotive, indifferently. When the wind blows lengthwise of the car it is necessary to run water into the axle boxes of the truck in the leeward direction, as otherwise the intense heat blown that way would burn out the journal packing in a short time. The weed-burning train carries, besides the burner car, an oil supply car (usually a stock car loaded with barrels of oil) and a boarding car for the crew. Each of these trains covers 310 to 425 miles of track burned three times each season.

210. Buhrer Concrete-Steel Ties.—In Sec. 169 there is a description of the concrete-steel tie with which Roadmaster C. Buhrer, of the Lake Shore & Michigan Southern Ry., has been experimenting since the spring of 1902. The details of design appear in Fig. 539. The ties are 8 ft. long, and each is reinforced with a piece of rail 7½ ft. long, made by cutting old scrap 60 or 65-lb. rails into four pieces. The concrete body of the tie projects 3 ins. beyond the reinforcement at each end. The metal top face projects ½ in. beyond the concrete body, so as to shed water, and the width of the concrete along the middle portion is 3 to 4 ins., from top to bottom (see Section *C-D*), being narrowed in order to diminish the width of bearing and thus avoid center binding of the track. To provide for the insertion and removal of fastenings there is a recess in the concrete in each side of the tie, under the bolt hole through the top face. The concrete is a mixture of fine gravel and cement, and it is either submerged or frequently sprinkled with water with a hose during 30 days while it is setting.

These ties weigh about 400 lbs. each. It is fully understood that the use of old rails for the reinforcement involves a good deal of metal, undoubtedly in excess of the requirements; but as the principal aim of the experiments was to determine how the concrete would bear up under the traffic and sustain the shock of rolling loads, the excess of metal was of minor importance. The inventor has in view the possible use of various metal shapes for the top face of the tie, such as old rails of lighter weight than the ones used, T-irons, bulb irons, a channel with the flanges downward, and other shapes. Mr. Buhrer is confident that the weight of the necessary metal can be reduced to 80 lbs. or less. The ties are handled by means of tongs made to take hold under the bottom of the tie, and when placed in the track the fastenings are screwed up by means of a socket wrench made by placing a brake wheel on a shaft and forging the bottom thereof to fit the heads of the bolts.

Besides the roads already named as having these ties on trial, the Ann Arbor R. R. (near Durand, Mich.), and the Pennsylvania Lines West (at Toledo, O., and at Allegheny, Pa.) are making tests of experimental sections of main track laid with them. The experiment at Danbury, O., on the Lakeside & Mar-

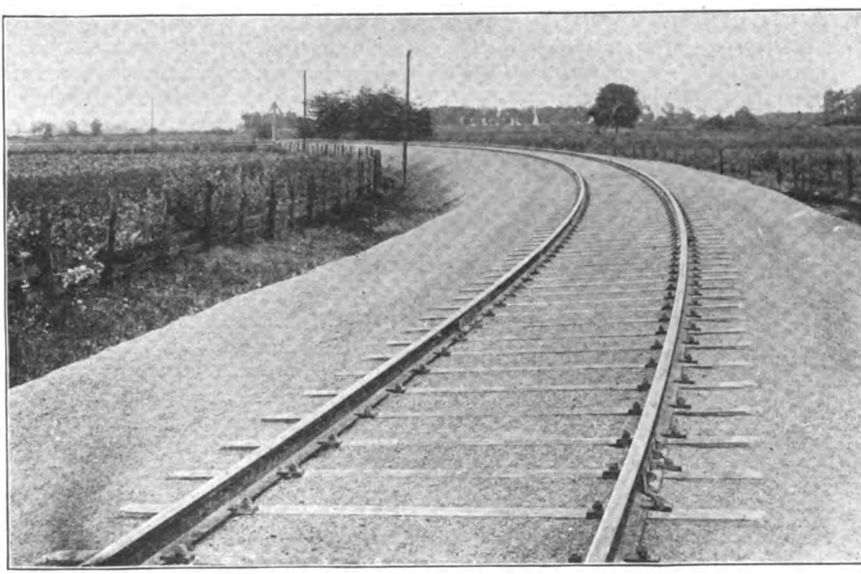


Fig. 540—Track Laid with Buhrer Concrete Steel Ties, L. & M. R. R.

blehead R. R., was started in July, 1903, on a compound curve of 12-deg., 9-deg. and 6-deg. parts, about 1200 ft. long, laid with 17 ties to the 30-ft. rail. Part of the curve is shown in Fig. 540. Over this curve there is a traffic of six passenger trains each day, and a very heavy freight tonnage. Before the concrete ties were laid the wear to the outer rail had been excessive, there had been difficulty in maintaining the rails in gage, and the services of the section men had been frequently called upon to adz the ties in order to return the inner rail from a canted position. When the new ties were placed the track was relaid with new 75-lb. rails, to a gage of 4 ft. 8¾ ins., and ballasted with limestone screenings. On this trial section there is a turnout, and, to demonstrate the feasibility of using these ties in any place where wooden ties can do service, this turnout was laid with concrete ties. Not only the ties under the lead rails, but the headblock for the switch stand is reinforced concrete, made up generally on the same design as that of the ties of standard length.

At latest reports the track at Danbury had remained in good surface, line and gage at practically no expense for repairs or attention, and the service of the ties had been highly satisfactory On the various roads mentioned these ties have been laid in both gravel and broken stone ballast.

It is interesting to state further that in some cases these ties are being used in the track circuits of automatic electric block signals, on both the L.

S. & M. S. Ry. and the Pennsylvania Lines West. The means of insulation consists of oak shims ¼ in. thick., in some cases, and fiber shims in others, placed under the rails, with fiber bushings and washers for the fastening bolts and clips. In some of these trials only one rail (that is, only one side of the track) is insulated from the metal top face of the tie.

211. The Ware Pneumatic Rail Unloader.—Section 146 covers the use of machines and appliances for unloading rails from cars where access to the rails can be had at the end of the car without lifting the rails, as with gondolas with removable ends and box cars with end doors, but rails are frequently shipped from the mills in gondola or deep steel cars with permanent ends. Mr. Henry Ware, roadmaster with the Buffalo, Rochester & Pittsburg Ry., has designed and used apparatus for handling rails out of such cars. The machinery (Fig. 541) consists of two skids or incline troughs, over which the rails slide from the rear of the car, with pneumatic hoisting apparatus for lifting the rails from the pile in the car to the level of the skids. On each side of the car there is an upright, which is secured to the side of the car by means of an adjustable stake pocket and two adjustable brace rods. It can be placed on any kind of a car having open sides. On the inside of each upright a roller is permanently secured at an elevation about 10 ins. above the level of the top of the car, and there is also a roller at the top end of each skid or incline, which is hooked over the end of the car in line with the roller on the upright. The trailing ends of the skids are supported by a 5x5-in. piece of timber crosswise the rails, carried upon two small wheels. All parts of the machinery are detachable and can

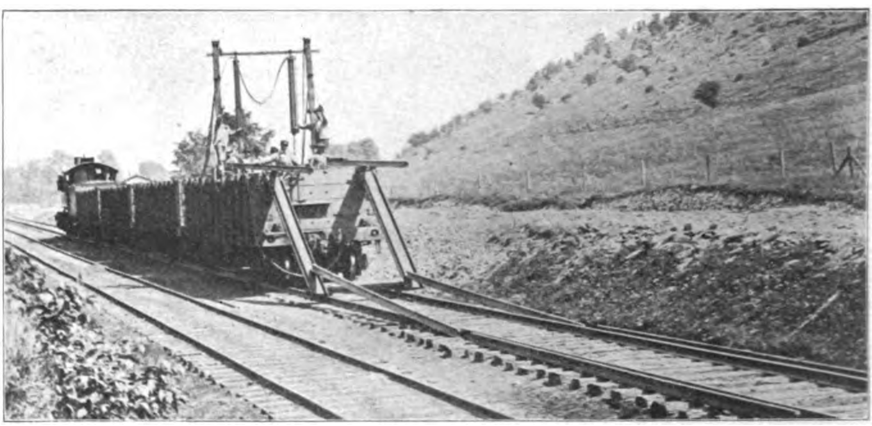
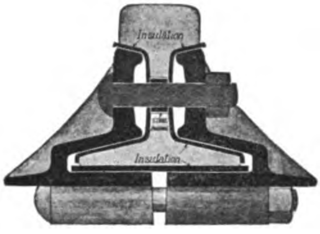


Fig. 541—Ware Pneumatic Rail Unloader, B., R. & P. Ry.

be removed or attached without the aid of tools, except in the case of the stake pocket, which requires the use of a spike maul to drive the wedge which makes the adjustment of the pocket to the various widths of the car sides. The pneumatic hoists are suspended from a cross bar supported by the two uprights. The compressed air used is taken from the train brake line through a flexible hose. In unloading rails three men are required to handle the rail and tongs, and one to manipulate the working of the air for the cylinder, on each side of the car, or eight men to unload and distribute rails from both sides of the car at the same time.

In operation the suspended tongs are attached to either the head or base of the rail, whichever is most convenient for grappling, and the rail is raised to a sufficient hight to guide it onto the rollers. The air is then released, the tongs detached and the men push the rail over the rollers. When the center of the rail reaches the roller on the skid the rail tips up, the end of the rail slides to the ground, and, as the train moves ahead, the upper end of the rail gradually slides down and is landed on the ends of the ties, just outside of, and clear of, the service rails, without further attention after they enter the skids. Each car, as it is unloaded, is cut off from the train and allowed to stand on the track while other cars are being unloaded, or until it is pushed to a siding by the regular traffic, when all the empty cars can be left on the siding or coupled in next to the engine and hauled along with the train. On some roads rails are unloaded with steam derricks or wrecking cars. In such cases the train is obliged to return to a siding after unloading each car, in order to make a shift



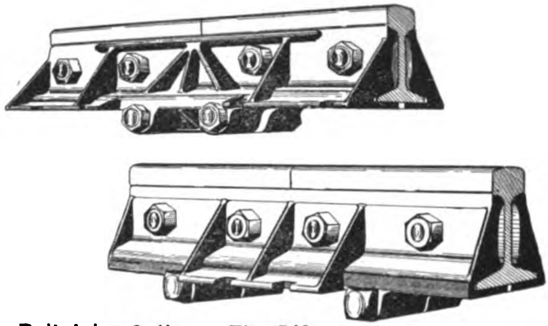


Fig. 542—Atlas Rail Joint Splices—Fig. 543.

of cars to get the next car of rails to be unloaded ahead of the derrick. This machinery obviates the necessity of running to sidings to shift cars.

212. Rail Joint Splices.—The Atlas joint splice consists of two malleable iron or cast steel bars, grooved to fish with both the bottom and top of the rail flange, as well as with the under side of the head. The sides of the bars are gusseted or ribbed transversely (Fig. 543), and there are depending lugs with two bolts, under the rails, to draw the bars securely together at the bottom. The style of bar for supported joints is shown by the bottom drawing, and that for suspended joints by the upper drawing. The Atlas insulated joint splice is of the same pattern, being fitted with fiber sheet insulation under the base and at the fishing surfaces of the rail (Fig. 542), with fiber bushings for the splice bolts where they pass through the rail web. To relieve these bushings from wear they are protected with a metal washer where contact comes with the web of the rail.

The Wolhaupter joint splice consists of two grooved base-griping angle bars, with a separate corrugated base plate fishing into the bars. In Fig. 544 the lower half-tone view shows the outside bar, the upper view the inside bar, and the right-hand view a section of the splice at the middle. The base plate is shouldered along one edge to take the abutment or outward thrust of the rail flange, and on the gage side of the rail the base plate and the bottom part of the inside splice bar interlock, the horizontal leg of the splice bar being cut away at both ends and the base plate cut out at the middle. The inside spikes are driven in holes punched through the base plate, and bear against the edge of the rail flange where the ends of the splice bar are cut away. As the base plate is shouldered against the outer edge of the rail flange these inside spikes are as effective in holding the gage against lateral stress as the outside ones, and they hold the gage and alignment of the rails independently of the adjustment of the splice bolts.

Step Splices.—Mention may be made here of certain step or compromise joint splices not covered in Sec. 95. As the Atlas joint splice is shaped by molding and casting, it is readily made for step joints, and is much used for a compromise splice. The Vulcan step joint is made without splicing bars, merely by fitting and bolting the two rails together (Fig. 545). The rail of larger section is bent to a small angle and the head of the lighter rail is planed off to make a

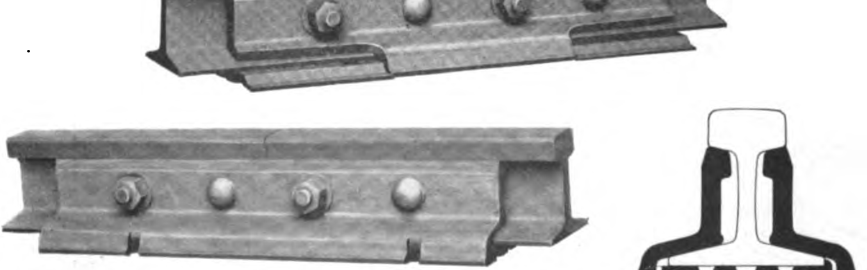


Fig. 544—Wolhaupter Rail Joint Splice.

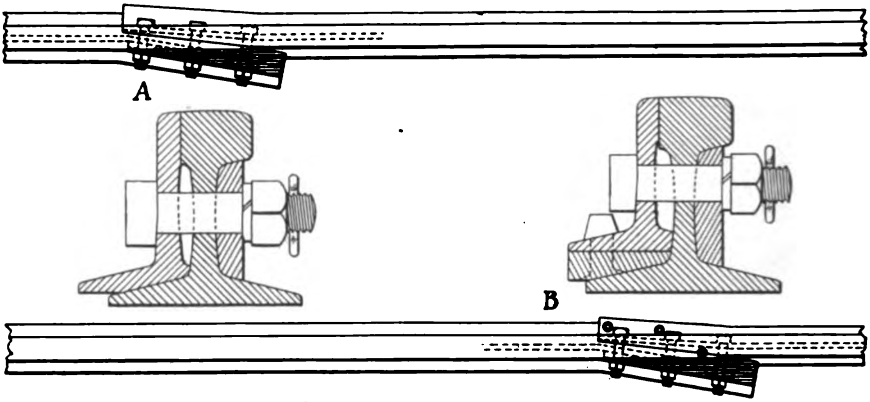


Fig. 545—Vulcan Step Joint.

miter joint with it, fitting against a shoulder at the bend, as shown. The base of the lighter rail is planed to rest upon the top of base of the heavier rail. Where the variability of the hight of the sections is great a metal shim is riveted to the base of the smaller rail, as shown by engraving *B*. The two are then bolted through and through horizontally with three bolts. The ends of the two rails lap about 12 ins., and outside of the rail head line the bent end is planed down on a bevel to put it out of reach of the false flanges of guttered wheel treads. This step joint is standard on the Atchison, Topeka & Santa Fe Ry., and is used on a large number of other roads.

213. **Mansfield Semaphore Switch Stand.**—In the development of railway signaling the semaphore has been gradually gaining ground as the standard and most satisfactory type of signal. Where a high signal is used at switches thrown by hand the semaphore has been widely adopted in preference to the revolving target. For a good many years the idea of working a semaphore signal in connection with ordinary hand-throwing switch stands has been in the minds of a few railroad men, and at one time a semaphore switch stand with the arm standing about 18 ft. high was used to some extent on the Pennsylvania R. R. The Chicago & Alton Ry. has adopted a semaphore signal and stand for switches thrown by hand. It was designed by Mr. Geo. L. Mansfield, assistant engineer with that road. The stand is also widely used on other roads. As seen in Fig. 546, the stand is thrown by means of a weighted ground lever operating a bevel gear in the column or base, which turns a revolving shaft passing up through a 1½-in. pipe tube screwed into the top table of the stand. At the top of this tube the shaft operates another set of bevel gears which actuates the semaphore 8 ft. high.

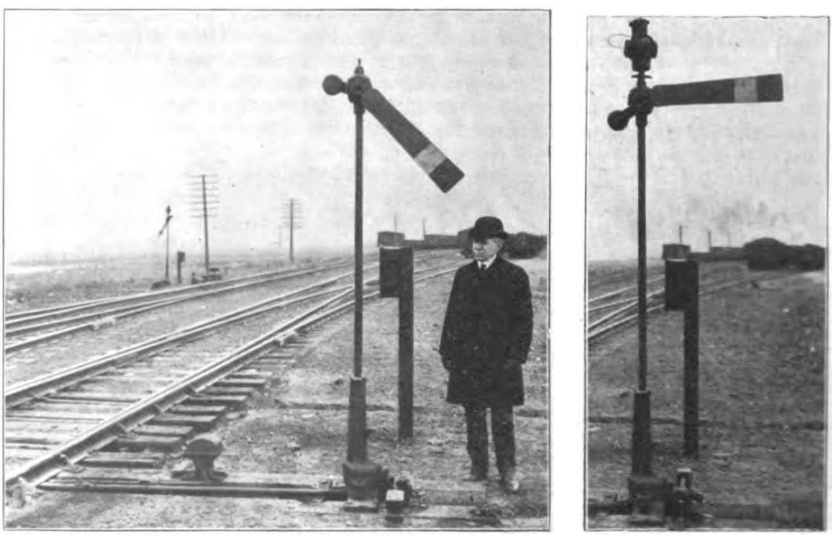


Fig. 546—Mansfield Semaphore Switch Stand, Chicago & Alton Ry.

As applied on this road, the stand was specially constructed throughout, but the design of the upper part, including the hollow mast, or tube, the gear mechanism and the semaphore, is such that it is adaptive to existing stands of the revolving type, of almost any pattern. When thus applied the top table of the stand is tapped out to receive the tubular mast supporting the semaphore, and the shaft operating the semaphore is jointed up with the shaft already in service. For a night signal the ordinary switch lamp is used on top of the revolving shaft, as seen in the picture at the right.

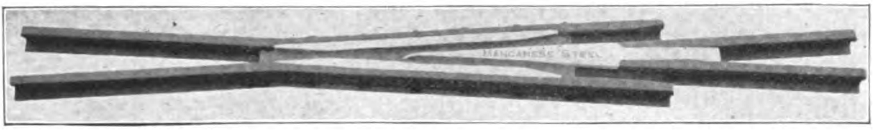


Fig. 547—Manganese Steel Frog Construction.

There is one difficulty with single-arm semaphore switch stands for single track, which does not arise with a signal of the revolving target type. In practice semaphore signals are supposed to govern the movement of trains only when approached in the direction from which the arm is seen at the right of the pole. As engineers are accustomed to regard semaphore signals only in this manner, it is clear that a single arm used on single track would govern trains running only in one direction. It is therefore the practice on some of the roads using this stand to equip it with a double arm. An extra arm is attached in place of the counterbalance shown, and in this way the stand governs trains running in both directions.

214. Manganese Steel Frogs.—An idea on improving the wearing qualities of frogs, which has been receiving considerable attention for some years, is the use of hardened steel for the parts which take the bearing of the wheels opposite the point piece and in the throat. One method of constructing frogs with such hardened parts is to bolt up pieces of rail in the ordinary manner of frog construction, with the wing rails bent around the hardened bearing pieces, all being bolted through and through, as in Fig. 91, Sec. 58. Another method is to cast the point and wearing parts of the wings in one solid piece, and then fit the legs of the frog to it. Such is the manner of constructing the Manganese steel frog (Fig. 547). The bearing parts on either side of the point and in the throat are one solid casting of manganese steel, which is made very hard. The wing parts of the casting afford a good width of bearing for the wheel tread. The bent wing rails of ordinary steel are then planed out to fit in with this part of the frog. The point rails are bolted on to either side of the heel casting in a manner to have the latter take part of the bearing. The wing rails are bolted on with reinforcing straps outside. These frogs have been in use on the Pennsylvania R. R. and some other roads in large numbers. One of them was laid in one of the main tracks of the Pennsylvania R. R., west of the Broad Street station, in Philadelphia, where the wear and tear from the very heavy traffic is so great that no frog of ordinary carbon steel was ever able to last longer than three months. At the end of 37 months this frog was still in use, and in fair condition, with prospects for a further service of many months.

215. The Oscillating Cattle Guard.—As animals are afraid of an insecure surface under their feet, the principle has been applied in the construction of a cattle guard that will swing so easily that stock will not obtain a sufficient foothold to encourage them to attempt to walk over it. The Oscillating cattle guard consists of a wooden slat device built 9 ft. long, with slats spaced ¾ in. apart and spiked to wooden bolsters, in three sections. The bolsters rest upon steel cross bars, being fastened by saddle clips to which the bolsters are bolted.

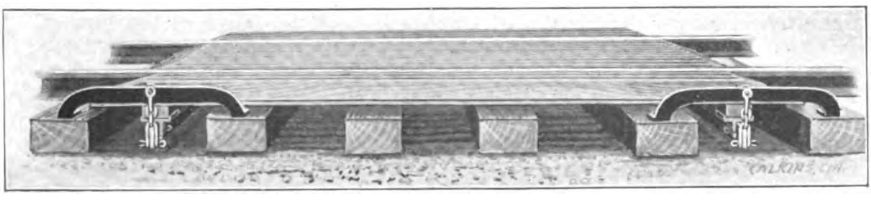


Fig. 548— The Oscillating Cattle Guard.

These saddle clips project down on either side of the cross bar in a manner to hold the bolster closely to the bar. Each cross bar hangs under, and 1 in. clear of, the track rail, in a space between ties, and is supported at each end by a chain hung upon an arched bracket resting upon, and bridging the interval between, two ties, as shown by Fig. 548. The bottoms of the slats clear the tops of the ties by an inch, and no part of the guard extends above top of rail, so that it cannot interfere in any way with the operation of snow plows. If desired, the two slats next the rails can be removed to permit unobstructed operation of snow flangers. The removal of the guard in whole or in part, as to make more room for tamping ties or for shimming the rails, is conveniently and quickly done, as it is only necessary to take out the cotter pins which secure the saddle clips holding sections of the guard to the cross bars.

216. Tie Plates.—The features of the Hart tie plate, shown at the right in Fig. 549, are described in Sec. 11. The Chicago tie plate, shown at the left in this illustration, has a side sloping top, with four rows of raised bosses to take the bearing of the rail, as shown in elevation by the upper engraving. The sloping top is intended to drain off water, brine, sand or grit. The Federal tie plate, shown as the central engraving of the illustration, has a top sloping from

Fig. 549—Various Tie Plates.

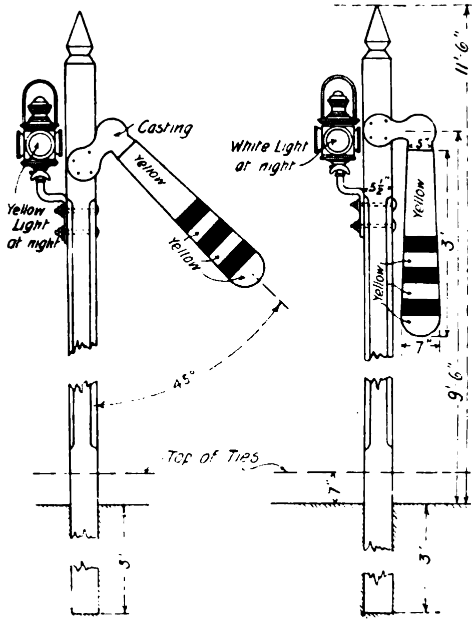
center, with raised boss bearings for the rail, but only one under flange to hold it to the tie. This flange is central with the plate, is thin and has parallel sides. This plate is made by rerolling the base and web of old rails.

217. Speed Regulation Signals for Curves, P. L. W.—On the Pittsburg, Ft. Wayne & Chicago and the Pittsburg, Cincinnati, Chicago & St. Louis (Panhandle) systems of the Pennsylvania Lines West a signal is used to regulate the speed of trains at sharp curves. It consists of a post standing 11½ ft. high above the ground and 7 ft. from the gage line of the rail, with a semaphore arm in a fixed position, as shown in Fig. 550. The semaphore arm is attached to a casting which is spiked to the post. The face of the arm is painted yellow, with black bars, the appearance suggesting the local name of "coon tail" signal. The back is painted white. At sharp curves, where it is considered necessary to reduce speed, the slow-up signal arm stands at an angle of 45 deg. with the post, which is placed 1000 ft. in advance of the point of curve. The signal for resuming speed is a semaphore arm hanging vertically, or parallel with the post, and the signal is placed at the end of the curve. The drawing shows a lamp attached to the post. It was originally intended to use lights on these posts at night—a white light with the signal permitting full speed, and a yellow light with the slow-up signal, but this plan was not put into practice at the start.

218. American Rail Loader.—The American rail loader is quite similar in construction to the Laas pneumatic machine, described in Sec. 146 and illustrated by Fig. 369. The principal difference is that the former is made to run on the top edges of the sides of a gondola car, and hence can be used on such cars when the ends are closed. The truck wheels are adjustably attached to their axles, and by this means their gage is readily changed to the requirements.

219. Hedge Snow Fence.—On some of its divisions the Intercolonial Ry. has pursued the plan of cultivating hedge snow fence wherever the trees will grow, and many examples of thriving trees on the line of the snow fences may be seen. Fir and spruce are set out on the track side of the fence, and by the time the fence decays the growth of trees will take the place of the lumber fence. Trees 10 to 12 years old attain a hight of 8 to 12 ft., growing bushy near the ground and standing close enough together to serve the purpose of a snow fence excellently. In order to maintain a bushy growth the trees are trimmed to a hight of 12 ft. and are not permitted to permanently exceed this hight. At many points on the Northern Pacific Ry., in North Dakota, rows of cottonwood and willow trees have been set out back of the board snow fences, and have thriven well.

220. Nickel Steel Rails.—Experimental use of nickel steel rails for six years seems to indicate that rails of such material will outwear three or four



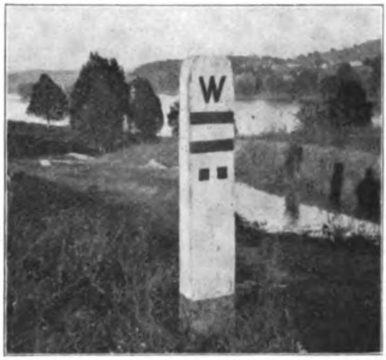


Fig. 550—Speed Regulation Signals for Curves, Pennsylvania Lines.

Fig. 551—Whistling Post, Southern Ry.

sets of carbon-steel rails. Nickel-steel rails laid in a freight track of the Pennsylvania R. R., at Kittanning, Pa., lasted three years, as against 10 months for rails of ordinary steel.

In addition to the roads mentioned in Sec. 197 the following others are experimenting with nickel-steel rails: Bessemer & Lake Erie R. R., the Union R. R., and the New York Central & Hudson River R. R. At the West Albany Hill on the road last named 204 tons of nickel steel rails were laid in 1903, in sections adjacent to, and opposite, sections of ordinary steel rails in the same track. The chemical composition, besides the iron, was found to be: carbon, .418 per cent; silicon, .102 per cent; manganese, .79 per cent; phosphorus, .094 per cent and nickel, 3.38 per cent. Some frogs made of the same steel are also under trial.

221. Coughlin-Sanford Switch Point Lock.—The Coughlin-Sanford swing-rail frog (Sec. 58, Fig. 95) is now worked in connection with a switch point lock. The target is on a separate stand from that which throws the switch and is worked by the lever of the switch point lock. The point lock consists of a plunger rod working through a slotted casting, with connections to the switch points so arranged that the plunger is blocked until the switch points have been thrown fully up to the stock rail. Should a lump of coal, an icicle or other obstruction fall behind the switch rail, or the switch point get out of adjustment, it is impossible to move the lock lever or give a clear signal. The lock lever is the one to which the switch padlock is applied, and when thrown to the locking position it lies directly over the ground lever of the duplex stand which throws the switch and frog. It is therefore impossible to open the switch without first moving the signal and lock lever, withdrawing the lock plunger and setting the signal in the danger position.

INDEX.

Note.—Pages marked with a star (*) contain an illustration of the subject referred to.

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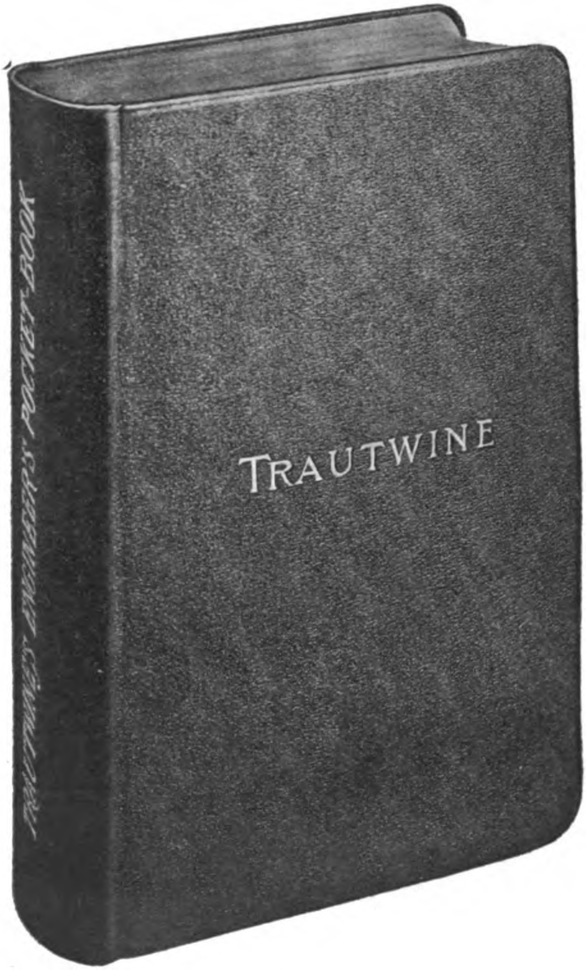

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