THE ADMINISTRATION OF
THE DEPARTMENT OF
TRACK, BRIDGES, BUILDINGS AND WATER
SERVICE OF RAILWAYS.

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RAILWAY ORGANIZATION.

INTRODUCTORY. With the vast increase of capital invested in railway interests there has grown up a characteristic system in the administration of railway affairs. The lines along which this administration naturally subdivides itself are given as follows:

1. The financial department, which provides the ways and means.

2. The construction department, which builds the railroad after the ways and means are provided.

3. The operating department, which operates the road after it is built.

4. The commercial department, which finds business for the operated road to do, and regulates the rates which are to be charged for doing it.

5. The legal department, which attends to all the numerous questions arising in the practical working of the other departments.

While each of the above departments enters into the organization of every railroad in some form or other, there is wide diversity in the division and distribution of official responsibility and

authority adopted on different lines, and often a similar variety of plan is found on the same road at different periods of its corporate life. The following outline shows the official designation of the head of each department as used on a number of representative railway systems:

```
FINANCIAL DEPARTMENT.

1st VICE PRESIDENT...COMMERCIAL DEPARTMENT.

PRESIDENT...

2nd VICE PRESIDENT AND GENERAL MANAGER.

CONSTRUCTION DEPARTMENT.

OPERATING DEPARTMENT.

GENERAL SOLICITOR....LEGAL DEPARTMENT.
```

OPERATING DEPARTMENT. The operating department embraces the running of trains and the physical care of the property and equipment. The former of these functions involves not only the train service proper, but also its essential adjuncts, the telegraph and station service, and the related features of the motive power service. The care of the property is entrusted to the mechanical and roadway departments, which have in charge the maintenance of the motive power and rolling stock, and the permanent way and structures, respectively. These functions are set forth in the following outline:
GENERAL SUPERINTENDENT
in charge of OPERATING DEPARTMENT.

RUNNING TRAINS

DIVISION SUPERINTENDENTS
in charge of TRANSPORTATION DEPARTMENT.

Motive Power and Rolling Stock.

TRANSPORTATION DEPARTMENT.

SUPERINTENDENT OF MACHINERY
in charge of MECHANICAL DEPARTMENT.

Motive Power Service.

Station Service.

Locomotive Service.

Car Service.

Engineering Service.

Track Service.

Bridges and Buildings Service.

Water Service.

MOTION POWER and Rolling Stock.

ENGINEER OF MAINTENANCE
of WAY
in charge of MAINTENANCE OF WAY DEPARTMENT.

Permanent Way and Structures.
MAINTENANCE OF WAY DEPARTMENT. It is the purpose of this thesis to consider and discuss the administration of the department of track, bridges, buildings, and water service, or, as commonly designated, of the maintenance of way department. The data used and the methods described will be drawn chiefly from the writer's experience on the Gulf, Colorado & Santa Fe R.R. in Texas, and comparisons will be made principally with roads in the Southwest. The discussions will be directed to the end of suggesting improved methods of administration.

The four essential divisions of service in the maintenance of way department, introduced in the foregoing outline, may be further described as follows:

1. The engineering department, which in addition to its usual duties, will here be assumed to have executive charge of all classes of the maintenance of way service.

2. The track department, to which is assigned the maintenance of the roadway or track proper.

3. The bridges and buildings department, which performs a similar function with relation to the bridges, buildings, and other structures.

4. The water service department, which has in charge the maintenance and development of the supply of water for locomotive and other purposes.
Executive Officer. There is a somewhat decided division of opinion and also of practice in the assignment of executive power over the maintenance of way department. While many first-class railway systems adhere strictly to the plan of entrusting all branches of this department to specially trained civil engineers, not a few very capable managers and superintendents insist that this class of service should be under the general direction of a man whose training has been confined to the practical side of the work. In some instances of the latter kind, however, the maintenance of way service is divided into two general classes, the track, and the bridges and buildings departments, the latter usually including the water service, and these are placed under the direction of two men, respectively, who report independently to the general superintendent or, in some cases, to a division superintendent. Since a large majority of railway superintendents attain official preferment through channels which are entirely foreign to the practical features of maintenance of way service, much too often they are able to perform with efficiency and economy little beyond a merely clerical function in that department of service. While most superintendents having such powers in the course of time acquire a knowledge of detail requisite to the smooth administration of affairs, it must be admitted that on the whole the system is defective when contrasted with the obviously natural plan of vesting these powers in specially qualified civil engineers, subject to the general direction of a higher
Furthermore, the latter system is supported by the fact that railroad location and construction are universally recognized as legitimate functions of the civil engineer. For it would seem eminently logical that the same class of men, and with certain restrictions of a practical nature, the identical men who locate and direct the construction of a railroad, should subsequently have in charge its maintenance. Such a system, in effect, is found on a number of roads where the construction and maintenance departments are blended together to a greater or less extent. The wisdom of the general principle thus carried into practice has been forcefully expressed by an eminent engineer in the following words: "That true economy which finally secures in a completed work the best results from the invested capital, in first cost and continued maintenance, is an essential element in the consideration of any really great engineering feat."

On the other hand, it should be observed that however perfect any such system may be in theory, its maximum possible efficiency is very certain never to be attained or even approached under the oscillating and semi-political administration which prevails upon many extensive railway systems in this country at the present time. In fact, it may be asserted as an established truth that with certain restrictions of an obvious character, the efficiency of any policy in the administration of railway affairs depends to a large extent
upon the element of permanency in the tenure of position as a reward of faithful service. The ideal system of administration is that which on the one hand neither seeks to compel diligent service solely through fear of dismissal, nor on the other permits the practice of habitual inaction, but which stimulates efficiency and genuine loyalty of service by making reward at least as certain and as just as penalty in its application.

Experience has shown that under ordinary conditions, the best length of division to be assigned to one division or resident engineer is about five hundred miles. This division is best divided into five approximately equal portions, each to be assigned to the care of a division roadmaster, or supervisor as the position is designated in some parts of the country. For the efficient administration of the department of bridges and buildings, it is found wise to divide the residency into two practically equal divisions, each to be put in charge of a division bridgemaster. Usually it is practicable and better to put the entire division of five hundred miles under the direction of one foreman of water service, who may have two or more assistant foremen with powers somewhat analogous to those of a foreman in the other departments.

The following organization of the maintenance of way forces has been found in the experience of the writer to fulfill the demands of a road having a wide variety of conditions to deal with, and it will serve as a basis for the discussions given in the succeeding pages.
FOREMAN OF WATER SERVICE.

Assistant Engineers.

Assistant Repairs.

Assistant Helpers.

Assistant Inspectors.

Assistant Bridge Watchmen.

Assistant Drawbridge Tenders.

Assistant Laborers.

Assistant Painters.

Assistant Carpenters.

Assistant Foremen.

Assistant Rodmen.

Assistant Chainmen.

Assistant Axemen.

Assistant Painters.

Assistant Carpenters.

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Assistant Axemen.
ENGINEERING DEPARTMENT

OFFICERS. Since the executive function is assumed to be vested in the hands of engineers, consideration will first be given to the engineering department of the maintenance of way service.

Engineer of Maintenance of Way. The engineer of maintenance of way should be specially fitted both by training and temperament to meet with success the requirements of his position. His education should have a thoroughly technical foundation, and he should have that intimate knowledge of the details of his work which is acquired only by observation and experience in a responsible subordinate capacity. The length of the preparation period requisite to efficient service depends in a large measure upon the man himself. For men of like mental capacities and tendencies, it is probably about inversely proportional to the extent and quality of their early technical training. In temperament he should be cool and deliberate at all times, and especially under the stress of emergency should he be able to grasp all essential facts and conditions and to form with promptness a sound and safe judgment. In order that he may exercise a wise discrimination in the employment of men, he must not only be thoroughly conversant with specific requirements in each line of service, but he must especially be a keen judge of human nature.
The latter quality is furthermore essential to the equitable administration of disciplinary measures, for while rules of service and personal conduct should in the main be inflexible in their application, their rigid enforcement under certain extenuating circumstances may defeat the real purpose of the discipline by losing the respect and confidence of the servants to whom the rules apply. In any event, while the executive should exercise his powers with great firmness, he should not confound that valuable quality with unreasoning obstinacy. In brief, the engineer of maintenance of way should not only be a good judge of both men and materials, but he should also be able to combine the two effectively and economically to the accomplishment of the end in view.

Division Engineer of Maintenance of Way. The division engineer of maintenance of way should, from the nature of the case, be a man who aspires to the superior position and will be eligible to such in the course of time. Consequently, he should possess the essential qualifications, at least as regards temperament and technical training, which have been specified for the higher official position, although some deficiencies, due solely to lack of development in the man, may for a time be excused. Since his superior can not come into close personal contact with the various classes of servants in the department, owing to the more general character of his duties, it falls to the division engineer to report promptly and
fully all matters pertaining to the service that may assist in the 
intelligent performance of the executive function. To this end, the 
division engineer should not only be a keen observer and have a re-
tentive memory, but he should also have the ability of stating 
facts forcefully and concisely, either verbally or in writing. 
Since he should be the best posted man on his division, he must not 
allow his superior to outdo him as a searcher for facts and in de-
veloping the quality of inquisitiveness, especial attention must be 
given to training the eye. Since the division engineer daily comes 
in contact with his subordinates, the enforcement of matters of dis-
cipline is in a degree more difficult. In order that he may with 
success be firm in such matters, he must at all times and under all 
circumstances "treat men like men".

Office Engineer. It is of much importance that the engineer 
of maintenance of way should have an engineer in charge of his 
drafting and other office work. The office engineer should be a 
man who has earned a good reputation in the field, is familiar with 
the local requirements and conditions of the various portions of the 
road, and is able to perform creditably the work of the chief 
draftsman in case of necessity.

Draftsmen. There is need ordinarily of a chief draftsman and, 
in times of rush, of one or more assistant draftsmen. It is essen-
tial that the draftsman should be able to execute quickly a neat,
accurate, and tasteful map or drawing rather than that he should be qualified to perform work of an elaborately artistic or fanciful character. The draftsman should have a thorough knowledge of and a sufficient experience in the fundamental operations of engineering drafting. The chief draftsman should have sufficient tact in handling men that he may successfully direct the work of his assistants.

**Assistant Engineers.** The engineer of maintenance of way requires one or more assistant engineers to perform the routine field work which does not properly fall within the scope of the division engineers duties. Besides, each division should be allowed an assistant who may be classed as rodman, although able to perform reliably the usual instrumental field work. The assistant engineer should be a man who aspires to promotion to one of the higher positions in the department in which he is engaged. In addition to his ability to perform reliably and well the work assigned to him in the field, he should have skill as a draftsman in order that he may be of service in case he is called upon to work in the drafting room. There should be on his part a keen interest in the requirements of the engineer's office, and he should be ready to improve upon or modify his methods in the field if necessary to comply with the personal preferences of the office engineer or chief draftsman. He should know the value of taking reliable field notes and presenting them in a form that is easily interpreted by a person who is
entirely ignorant of the premises, and to this end should not hesitate to embody in his notes liberal sketches and supplementary memoranda.
ROUTINE DUTIES. The engineer of maintenance of way must of necessity devote no small degree of attention to matters of general policy in the administration of his department. He must consider the detail of disciplinary measures, and to this end must give close consideration to the formulation of rules for the government of the forces belonging to the maintenance of way department. In the execution of the matters coming to his hands daily for action, he must weigh available information and facts with promptness and certainty, and must be able to supplement the statements before him from his personal store of knowledge of the local conditions in the cases under consideration. He must be a constant and close student of the reports of inspectors and other employes engaged in estimating and reporting the physical condition of structures, in order that he may adopt and adhere to a fixed policy in relation to the approval of requisitions for material to be used in the repair and renewal of these structures. In order that prompt action may be taken to relieve the stress of emergency on one division by borrowing from another, the engineer of maintenance of way should keep at hand, and preferably in mind, as well, a record of bridge and other material which is kept at various points on the road. He must co-operate fully with the auditing department in securing an accurate distribution of the accounts of his department, and to this end, must be
personally familiar with the system of accounting, and must enforce a similar familiarity on the part of his division engineers, and also of the chief clerks in his own and the division engineers' offices. He must scrutinize very closely the monthly pay-rolls with the view to prevent unjust discriminations in either direction in the rates of pay allowed to the servants engaged in his department. In order that he may have the means of reducing or increasing the expenditure of the department most wisely, systematic summaries and classifications of the preceding month's pay-roll should be made on regular printed forms, and such extracts from these statements as may serve to stimulate those who have had direct charge of the forces in the execution of the work, should be transmitted in proper form, a comparison with the expenses of the preceding month being included. Such comparisons have the effect of stimulating the heads of the track and bridge departments, and they also serve as a basis for the reduction or increase of forces.

The division engineer must necessarily put in a good proportion of his time on the road in inspections and in the transactions of the numerous details of business which are transmitted to him from a higher authority. He must keep in close touch with both his superior and subordinates, in order that the policy of the administration may be carried into execution with certainty. He must be thoroughly conversant with the cost of maintenance of each portion of
his division, and should make it a constant custom to analyze the
cost of the work under his care, in order that he may act with his
eyes open whenever modifications of the forces are ordered. He
should be so familiar with local requirements that he will never
make requisition for material or recommend work, the necessity for
which he can not sustain by substantial arguments in case opposition
is offered by his superior. In his office work, he should adopt
systematic methods, and since much in the way of instruction must be
done by correspondence, it is of the first importance that he should
preserve a copy of all letters and reports sent out from his office.
He should prepare in duplicate a record of the various physical
features of all the track and bridge divisions under his care, keep­
ing with him enroute one copy in order that he may make memoranda
of changes noted from time to time. This combined record should
embody the following items: (1) a tabulated statement of the lengths
and limits of each track and bridge division; (2) a similar state­
ment in relation to the track sections on each division; (3) a sim­
ilar statement of the subdivisions assigned to bridge foremen; (4)
a tabulated record of the number and location, with a brief descrip­
tion of each bridge on the division; (5) a rail and joint record of
the various track divisions; (6) the location and a brief descrip­
tion of each water station; (7) the location of depots and other
important points not included in the above list; (8) record of
lengths and locations of sidings. Such a record is necessarily somewhat voluminous, so that it may be best to transcribe only the more essential details, such as the bridge record, for the current use of the division engineer while on the road, and establish a set of compact note books in which he may find the tie statements, expenditures, etc. from month to month. Other records which should be in the division engineer’s office are those of fencing, cattle guards, and track ballasting, and there is often occasion to know the local character of the soil. By adopting a systematic and comprehensive plan for these records the task of bringing them to a serviceable stage will be much reduced. It is needless to remark that such a set of records is of the utmost assistance in the intelligent administration of the affairs of the department, and furthermore, that they should never be looked upon as being absolutely complete. It is very desirable that these records should originate in the office of the division engineer, sufficient help being allowed him to bring them to a useful point, when they are to be transcribed for the benefit of the engineer of maintenance of way. As additions or modifications are made from time to time, memoranda of same should be sent to the main office so that the two records may be kept essentially the same.

The division engineer should have in charge all matters pertaining to surveys and fixing grade lines and alinement for bal-
lasting operations. He should be frequently on the ground, and when practicable, should participate in such surveys. Profiles should be made in his office and the grade lines laid under his immediate direction, according to the maximum gradient fixed by his superior officer. Among the more important details of routine engineering work is the measurement of the angle and the collection of other essential data which must accompany the order for a crossing frog. Work of this kind should be done under the immediate supervision of the division engineer owing to the expense and annoyance resulting from a blunder or an oversight in securing the data. The subject of crossing frogs is treated in detail in Appendix II.

Another problem often calling forth no small degree of skill is the readjustment of long tangent lines when ballasting track. This subject is treated quite fully in Appendix I.
TRACK DEPARTMENT.

OFFICERS. Division Roadmaster. The life of the track department is in the division roadmaster, since upon him must depend the character of the foremen who have actual charge of the detail of the track work. The ideal division roadmaster may be described as a man whose preparation, beginning with a good common school education, has included the creditable filling for a sufficient period of time the positions of track laborer, section foreman, and foreman of extra gang or work train. He should have an honest and manly character, and a cool and equable temperament. At all times he should be full of resource, and above all he should be a close observer, and a ready and reliable judge of men and of materials and conditions. Few men, as a matter of fact, fulfill all of the conditions just stated, and many who are entirely satisfactory otherwise, lack the educational requirement to a woeful degree. Those roads which for many years have recognized and proven the value of special training for such service, have the best roadmasters. While under certain conditions a man may become narrow by continuing in the service of a single road for a long term of years, such danger is entirely obviated by a system of graded inspections with prizes, conducted by the track supervisors in person #; for,

# The system here referred to was devised and first put into practice on the Pennsylvania R.R. in 1879 by Mr. Frank Thompson, General Manager.
such a plan not only educates the men by comparison of results under a variety of conditions, but it stimulates them to renewed effort to excel.

Section Foreman. The section foreman should be an honest, sober and industrious man, with at least a good common school education. In his demeanor toward his subordinates he should on the one hand be firm without being severe and domineering, and on the other considerate without being indulgent. While in the main it is his function to direct his gang in its work, he should not hesitate to lead it should occasion require. In time of danger he should never ask a man to take a risk that he himself would hesitate to assume. He should be a keen student of trackwork in general and of the section assigned to his care in particular, and his ambition to accomplish good results should not be limited to a short stretch of track adjoining his neighbor, as is too often the case. As a legitimate stimulant he should have in view a higher position than that which he fills, and to this end, he should redouble his efforts when necessity compels a reduction of track forces.

Foreman of Extra Gang. The desirable qualifications of the foreman for an extra or floating gang are in several important particulars different from those named for the section foreman. While honesty, sobriety, bravery, and industry are equally essential in the two, the extra gang foreman usually has in charge a much larger
force of men and from the nature of the work in hand must as a rule make each day a much more tangible showing for the expense incurred than is the case with the section foreman. In fact, as already stated in referring to the most desirable preparation for the division roadmaster, the position of foreman of extra or floating gang may properly be regarded as the stepping-stone from the lower to the higher official position, although the promotion is not always made in such order.
TRACK. Railroad track is made up of the substructure which consists of the roadbed and ballast, and the superstructure which includes the cross-ties and rails and the means of connecting the two. Consideration will be given to these essential features in the order named, and the routine of track maintenance will be outlined and discussed.

ROADBED. The dimensions usually adopted in railroad construction at the present time for the roadbed in earth are: for embankment, 14-ft. width and side slopes of $1 \frac{1}{2}$ to 1; and for excavation, 20-ft. width and slopes of 1 to 1. Owing to the pressure under which much of the railroad mileage in this country, and particularly in the West, has been constructed, a very considerable portion of the roadbed has not been built in strict accordance with the approved cross-sections. The deviations have very naturally tended toward the reduction of earthwork quantities and since the width is susceptible of easy measurement, dishonest practice on the part of contractors has been confined very largely to the steepening of side slopes by shifting slope stakes toward the center of the roadbed. The result of this very common defect is shown in Figs. 1 and 2, in which are indicated the evolution in form of cross-section of embankment and excavation, respectively. It is frequently found that embankments on cheaply built lines have
Fig. 1. Showing Evolution of Cross-Section in Earth Embankment.
Fig. 2. Showing Evolution of Cross-Section in Earth Excavation.
side slopes of about 1 to 1 as indicated in Fig. 1. Under the action of the elements the slope gradually adjusts itself to the natural angle of repose for the particular material used in constructing the fill, and if the process is not disturbed, the top width will in time be reduced to little more, and sometimes even less, than the length of the tie. The eroded material is washed down the slopes and is in part deposited at the foot, so that the evolution consists in the transfer of a portion of the earth from a higher to a lower level. In the meantime the edge of the borrow pit has been affected in a like manner so that the berm may finally disappear.

In the course of time, considerations of safety or appearance, or the preparation of the roadbed for ballasting operations, make it necessary to add material on either side. This widening is usually done by means of earth delivered by work train, and while the process is much more expensive in most cases than the use of scrapers, it is obviously the best where contiguous cuts and fills are being widened simultaneously. An advantage not possessed by the work train method of handling earth for widening banks is in the compacting effect which is secured by teams passing repeatedly over the earth after it is in place, but the former method may be made to serve very well provided the side slopes which are to be
covered with fresh material be thoroughly loosened by pick or plow. In widening embankments by work train, it is very common to leave the slopes too steep, owing to scarcity of material or unskilled supervision. The result is similar in character to that which followed the original construction as above described, except that the looseness of the earth used in widening aggravates the erosive tendency. Unless vigorous efforts be made to prevent further scour of the slopes by securing a growth of sod on them, the process above detailed will go on indefinitely or at least until by successive widenings the dimensions and slopes originally contemplated are attained.

Referring to Fig. 2, page 24, it will be seen that a similar transition of form in the side slopes has been in progress in the excavation. The slope originally staked out to be 1 to 1, has been constructed steeper than that amount, and as a result the earth is scoured from above and deposited lower down on the slopes. The side ditches become clogged, and, if neglected, the track becomes bad owing to the defective drainage. Very often such a cut, when deep, is drained by steepening the slope for a short distance back from its toe, but in time the material washes and scours down and ultimately the stable slope is attained.

The custom in former years of making the width from toe to toe of slope in excavation only 16 ft. has resulted in no small
amount of useless trouble and expense in maintaining even fairly
good track in such cuts, particularly when located at a summit so
that proper slopes longitudinally could not be secured for drainage
to the side ditches. And even where the gradient may be ample, the
material may tend to slide irregularly so as to make the maintenance
of good side ditches very difficult. Under such conditions the
only hope for removing the water from the track with sufficient
promptness, is found in the use of liberal slopes from the end of
the ties to the foot of side slopes, with sufficient distance be-
tween the two to allow a commodious ditch. This usually requires
a width of at least 20 ft. and many western roads which encounter
the so-called "gumbo" soil, have found it necessary to adopt a
standard width of 22 ft. which is to be reached in most cases by
subsequent widening by track forces, as material slides down from
the side slopes.

Where the cut is deep, an ordinary section gang with the usual
length of track to look after is not able to make much of a showing
in the work of widening, especially if the length of haul is con-
siderable. However, under ordinary conditions very excellent re-
sults may be secured by a gang of the usual size by diligent use
of a pair of dump boxes and a good push car, the work beginning
preferably at the mouth of the cut nearer the foot of the grade, or,
in case of a summit cut, at both mouths, the material being used in
the continuous widening of the banks adjacent to the excavation, unless urgently needed elsewhere. When the length of haul becomes too great to be at all economical for dump box and push car, the cut should be widened by means of teams and scrapers, the material being wasted as on construction, unless it may be delivered where needed on embankments more cheaply than it can be borrowed close at hand. In long shallow cuts which urgently need widening, the ditches may be cleaned out by casting the material up to the top of the slope, but such practice should be looked upon as decidedly objectionable owing to the certainty that the material will be washed back into the cut in a short time and will thus have to be handled a second time. This plan of disposing of material removed from side ditches is most fully justified where financial stress prevents the use of work trains or teams and scrapers; and the narrowness and length of the cut make the use of push car and boxes very dangerous on account of passing trains. Where absolute necessity compels the use of this plan of cleaning out side ditches, the material should at once be cast back to a distance that will effectually prevent its returning into the cut.

As above stated, it is of the utmost importance in widening embankments that the slopes to be covered shall be loosened so that the newly deposited material may knit to the old. The failure to appreciate the importance of this precaution has resulted in the
useless expenditure of large sums of money, the new material sliding down the surface of contact as soon as the bank becomes thoroughly saturated for the first time after the widening had been completed. Failure to loosen the slopes is almost certain to give trouble on any kind of embankment, but the probability of serious results is greatly multiplied in the case of railroad embankments on account of the jar from passing trains. In Fig. 1, page 23, is shown the slope that is usually taken by the earth used in the widening, it being usually steeper than the same material may with reason be expected to stand permanently. The only efficient remedy for this defect is competent engineering supervision for such work by which a sufficient quantity of earth shall be deposited at the foot of the slope. The widening should begin at the foot first because the material will stand best when so deposited, and besides there is danger that the work may be stopped from a sudden fit of economy before the work is completed, and in that case it will in the end be better to have a less length of roadbed widened in a permanent manner than that the entire season's work shall have to be repeated after a few years. Furthermore, if a considerable stretch of track is left with only the lower portions of the bank widened, the probability of a resumption of the work at the earliest opportunity will be greatly increased.

In seeking to secure permanence of the sloping surfaces of an
embankment constructed of earth, the question of natural slope is perhaps of no greater importance than that of securing a vigorous growth of sod. These two questions are often closely related, since the sod will not under ordinary conditions attain its most vigorous growth on slopes which are in the process of erosion. Still it is not infrequently found that a good growth of sod starts on a slope much steeper than that which the underlying soil would have attained ultimately had it not been so retained by the roots of the grass, and that it remains so through an indefinite period. In the Southwest a variety of sod known locally as the Bermuda grass is extensively used on railroad embankments. The Bermuda grass has exceedingly strong roots and its stems interweave and take root in a manner which makes it the ideal sod for this purpose. Unfortunately, however, its growth is weak in localities where there is not an abundance of moisture, so that it is chiefly serviceable in moist places, and particularly in the case of embankments through swamps where the tendency to slide out at the foot of slope is greatest.

A notable instance of this kind is found in the embankment through the "Black Locust Swamp" on the Montgomery branch of the Gulf, Colorado & Santa Fe R.R. This embankment has a length of upwards of a mile and varies in height from 8 to 15 ft. above the original bed of the swamp, and owing to the difficulties attending its construction, a temporary line several miles in length was built
and operated until a drier season allowed the work to be completed.

For some reason the contractor was allowed to use logs and stumps in the interior of the embankment. During the series of unusually dry seasons which chanced to follow the completion of the work, it is believed that much of this timber decayed, for in the course of 8 or 10 years afterward the bank began to sag very irregularly throughout its length. During the spring overflow of 1889 the bank was surrounded and for nearly two weeks almost entirely submerged by back water from the Brazos River, to which the swamp was contiguous. The bank was completely saturated, and with the recession of the water the semi-fluid condition of the material caused the development of a large number of slips of the berms into the borrow pits, which allowed huge sections of the embankment to slide out of place, leaving the track without support in a number of spots. A continuous personal inspection of the phenomena described led the writer to appreciate very fully the value of the Bermuda grass as a revetment for such extreme cases, for as the material would tend to slip out of place, the roots and stems of the sod could be heard to snap as though resisting a severe strain. The foot of the slopes had been protected by planting willows and other trees indigenous to moist places. While the roots of such trees served the usual purpose of reducing the sliding tendency, their efficiency in the case under consideration was reduced by the shallowness of the
roots, for the trees seemed to move laterally with the berm without being tilted materially from their vertical direction.
BALLAST. The ballast is in reality merely a detail of the roadbed, but owing to the wide variety of kinds and qualities of ballasting materials, it is best considered separately. Ballast serves the double purpose of distributing the train load over a larger area of the underlying roadbed and affording prompt drainage for water which falls on the track. A good ballasting material will therefore be able to sustain the applied pressures without crushing or undue wear, and will be sufficiently porous to absorb, or to permit the ready passage of water. Besides these two essential qualities, which mainly involve the durability and efficiency of the ballast in actual service, the questions of availability as affecting first cost, and of its subsequent maintenance including the effect on the cost of tie renewals, should receive full consideration in choosing ballasting material. Still other features such, for instance, as the influence of dust on the comfort of passenger travel, sometimes demand undue attention, owing to the stress of competition, but ordinarily such considerations are of minor weight.

In many localities the choice of ballast is dictated by the question of availability alone. Such is true of a considerable portion of the Southwest, where the sources of ballasting material are so few and far between that there is seldom an opportunity to choose between two kinds, unless for ballasting operations of a limited
character. The scarcity of desirable material in that locality is perhaps best exemplified by the extreme distances to which ballast of inferior quality is often transported. A case on the Gulf, Colorado & Santa Fe R.R. may be cited as illustrating the seriousness of the ballasting problem for many of the railway lines of Texas. New steel rail had been laid on the Houston branch of that road, and the scantness of the shell ballast which had been put in the track many years before, made the re-ballasting of a portion of the stretch of new rail an imperative necessity. Diligent search for shell banks or other source of desirable ballast within a reasonable distance was made, but to no avail. A gravel pit, containing some very fair gravel, but averaging poor in quality, was being operated by means of a steam shovel at a distance of some 200 miles. The problem of protecting the rail became so urgent that the management of the road saw fit to deflect the product of the gravel pit to the Houston branch for several months. A conservative estimate showed this gravel to be an exceedingly expensive ballast under the conditions stated. Still, in view of the urgency of the case, the expense was doubtless warranted. Another instance of a long haul on ballast on a Texas railroad, which is more justly classed as wanton extravagance, is found on the Houston & Texas Central R.R. where gravel is hauled from a pit located on its Austin branch, and used for the purpose of widening embankments at remote distances
Kinds of Ballast. The kinds of track ballast most used on the Texas railroads are rock, gravel, shell, sand, and cinders. Owing to the cost of suitable fuel, burnt clay ballast has not as yet been introduced in the Southwest, although there is believed to be an abundance of clay and soil adapted to the manufacture of such ballast. The slag ballast, so prevalent in the neighborhood of iron manufactories, is also absent for a like reason.

Rock Ballast. In former years the rock used for ballasting track in the Southwest was in many cases left in its coarse condition, particularly on the poorer lines, where it was made to serve simply as a foundation to prevent the track from sinking out of sight in poorly drained cuts; and in cases where the coarse rock was broken up, it was usually done by hand with napping hammers. Within recent years, the extension into the Southwest of lines having headquarters in the North has resulted in the introduction of the power crusher for breaking the stone for ballasting purposes. Both lime and sandstones having qualities well adapted to the requi-

# In explanation of this case, it should be stated that the H. & T.C. R.R. has been persistently kept in the hands of the United States Court for a number of years, notwithstanding the fact that it is without question one of the best naturally located lines in this country, both for local and through traffic. The gravel pit referred to has served as one of a number on channels of indefinite expenditure by which a heavy gross earning has nominally failed to net anything to the owners.
quirements of first class ballast, prevail in Texas. Limestones are found, for the most part, north of the center of the state, and consequently are not as economical for use in the southern portion as the sandstones found within a distance of 150 miles of the Gulf coast. Most of these sandstone quarries are capped by an exceedingly hard ledge of flint which is said by geologists to be a hot water transformation of the softer stone found beneath. This flint behaves satisfactorily in the rock crusher, and the resulting ballast is first class in every particular. One objection sometimes urged against the flint rock is its tendency to crush into flat spawls which are longer and broader than the minimum dimensions specified for the ballast. This defect is easily overcome, however, by placing a man with a hammer on the ballast car, for the purpose of breaking up the larger spawls as they are delivered by the elevator.

One point of very marked superiority that the flint rock has over most kinds of limestone, is in the excellent quality of the screenings which are obtained from it. The screenings from crushed limestone do not make good track, as a rule, owing to the fact that they pack or cement together very soon after being put into the track, and for this reason it is necessary to provide quite steep lateral slopes to enable the water to run off readily. The screenings from the flint, on the contrary, do not lose their porous
character, owing probably to the quantity of sand that is combined with them, so that when used even sparingly, the result is highly satisfactory. This fact was determined conclusively in connection with an extensive contract for crushed ballast on the Gulf, Colorado & Santa Fe R.R. during 1890-2. The crusher was located in a flint quarry belonging to the railroad company, and strict inspections were maintained both upon the rock crushed and the resulting ballast. For some time after the ballasting operations began, the screenings were used in the construction of passenger platforms, wagon-ways, and other similar purposes, for which needs they served most efficiently. They were then used for a time in ballasting side tracks, and so successful was this experiment, that a trial in the main track was determined upon. A point on the Houston branch was selected for the experiment. The entire output of screenings was sent to the place selected, and a continuous stretch of track, several miles in length, was ballasted. Close study was given to the selection of a form of cross-section for the roadbed best suited to the screenings, and the conclusion was reached that the standard previously adopted for gravel ballast, given in Appendix, would serve the purpose. Subsequent observation proved this decision to have been wise, and, as above intimated, the experiment as a whole brought about a very decided change in the current opinions regarding the value of flint screenings as a ballasting mater-
ial, at least on the road where this experiment was tried. Inasmuch as the quantity of screenings usually averages about one-fourth that of the crushed ballast, an excellent opportunity is afforded to make a definite showing with the screenings, provided they are used continuously.

Gravel Ballast. Gravel is found in various parts of Texas, but owing to the extent to which it is combined with clay of soil, it is for the most part defective as a material for ballasting railroad track. Some gravel prevails in the central part of the state, which is apparently of first rate quality, but which, upon a close examination, is found to be defective because the pebbles have a thin coating of clay that has a soapy consistency when moist. Gravel of this kind has been used extensively in the absence of better, and as long as it remains dry, no trouble is experienced. As soon as the ballast becomes saturated, however, the clay film acts as a lubricant between pebbles which are in contact with each other, with the very natural result that the track suffers immediately in both line and surface. A few gravel pits which contain fairly clean gravel, are found to be objectionable on account of the coarseness and irregularity of the pebbles or boulders, which make it very difficult to secure refinements of surface in ballast­ing and maintaining the track. This defect is particularly notic­able in the gravel procured by the Southern Pacific R.R. at Glidden,
and by the Houston & Texas Central R.R. at Burton, Texas. After a careful examination of the product of pits in actual operation on other lines of railway, and an exhaustive search for new bodies of gravel in the territory contiguous to the Gulf, Colorado & Santa Fe R.R., the writer feels warranted in the conclusion that a really satisfactory gravel, in paying quantities, does not exist, or at least has not yet been developed, in the state of Texas. Notwithstanding this fact, the development of the limited quantities of fairly good gravel ballast which are in reach of most of the roads, may wisely proceed until the use of crushed rock or of a manufactured ballast is warranted by a cheaper cost.

Shell Ballast. Shell ballast, as its name implies, consists of the shells of various kinds of fish prevailing in the semi-tropical waters of the Gulf of Mexico. The shells are cast up into banks by the action of the waves and after the accumulation is sufficient to warrant the expense, a track is laid along the edge of the bank very much after the manner of operating a shallow gravel pit. The accumulation of the shell outside of the reach of ordinary tide-water is a very slow process, and it is quite certain that the more extensive banks of shell have had their origin in the tremendous force of the hurricanes which occur from time to time along the Gulf coast, and during which extensive areas of the flat country adjacent to the shore line is swept by the waves. Those
who have had an opportunity to use good shell ballast, almost uni-
versally look upon it as the ideal material for ballasting track.
It is porous and absorbent enough not to be affected in the least
by water falling upon it; serves most admirably as a foundation
material in wet localities by bonding together and forming a sort
of crust; it is sufficiently strong ordinarily to resist the loads
and abrasion imposed upon it as ballast; and is especially valuable
because of the cheapness with which it is handled in all details
of track work.

Probably the most extensive ballasting operations yet carried
on with shell ballast alone are those executed some years ago on
the International & Great Northern R.R. This work consisted of the
ballasting of upwards of 100 miles of track with an average of
probably above 2500 cubic yards of shell to the mile, aggregating
in the neighborhood of 300,000 cubic yards. The shells were ob-
tained by the construction of spur tracks to the shore of the North
Bay where it parallels the line of the road between Galveston and
Houston. One shell bank in particular, located at an especially
exposed point of the shore line, is said to have been the largest
ever operated for ballasting purposes. This bank had a depth of
19 ft. in places and is said to have been upwards of a half mile in
length. The shell was handled for the most part by convict labor
at 50 cents per day, and the work as a whole presents an excellent
example of first class ballasting done very cheaply. The real test of the value of this ballast came some years after it had been completed, when, owing to a necessary retrenchment, the track forces were greatly reduced for a term of several years. During this period, the tie renewals were sadly neglected, so that with ballast of ordinary kinds, the track would undoubtedly have been very dangerous but with the shell ballast, there was remarkable immunity from accidents chargeable to defective track. A very fortunate quality of the shell ballast, especially with meagre track forces as in the case just mentioned, is the almost entire freedom from the growth of weeds. With other kinds of ballast, and particularly the gravels prevailing in that region, the expense of keeping the track free from vegetation is very considerable.

**Sand Ballast.** In various portions of Texas, sand is found which gives very satisfactory service as track ballast, owing to its containing sufficient bonding material to cause it to pack and weather well. In localities where other kinds of ballast are lacking, or are too costly to admit of their use under existing financial conditions of the road, beds of sand of this kind may be made to serve a most valuable purpose temporarily, if properly handled. It is believed by many good trackmen who have made the experiment, that it pays to ballast track with sand of good quality immediately after the construction of the road, because the track is cheaply
maintained with the sand during the period that the roadbed is shrinking, and the sand serves well as a substratum for the permanent ballast when the latter seems necessary or can be afforded. This fact was conclusively proven in the case of the Texas & New Orleans R.R., a part of the Southern Pacific R.R. system, the line being constructed through the swampy region of Louisiana and eastern Texas where the only ballast obtainable for a number of years was the sand from the pineries. Just before putting in the permanent gravel ballast, numerous borings were made to determine the actual depth of sand which had sufficed to keep the track in very fair condition. These borings showed a depth ranging from 4 to 8 ins, and averaging less than 6 ins. The sand used in this case was, perhaps, somewhat above the average in quality, but the conditions were also more severe than are ordinarily encountered. The case may, therefore, be taken as fairly proving the belief that sand is not usually accorded the credit as a ballasting material that it deserves.

An important distinction should be made, however, between sand which is selected because of its evident value as a ballast and that which the trackman has to contend with in various parts of the post-oak timbered districts of central Texas. In the locality referred to embankments are constructed from the prevailing sand which is of a light and unstable character, easily washed and acting much like quicksand when wet, and worst of all, perhaps, blowing
out of the track when dry. This sand is, in fact, so fugitive in
dry and windy seasons as to make the track actually dangerous, owing
to the possibility of the formation of "sun kinks" at the foot of
grades with the removal of the lateral friction afforded by the
ballast. Another objection to this sand is in the rapid decay of
ties which come in contact with it. Whether this defect is due to
the presence in the sand of an injurious chemical element, or simply
to the alternating extremes of dryness, which cracks the tie open,
and of moisture, by which the heart of the tie is attacked with dry
rot, is not known. Judging, however, from the behavior of ties in
occasional intervening stretches of sandy clay, the latter theory
seems the more plausible.

Cinder Ballast. The cinders and ashes resulting from the use
of coal as a fuel for locomotives form an important source of bal­
lasting material on most lines of railway in the Southwest. The
finer cinders coming from the front end of the locomotive are found
to be too light for efficient service as a ballast when employed
alone, but as these are usually mixed with the coarser ashes and
cinders at the ash pit, it is seldom that a great quantity of the
finer material must be used by itself. Cinder ballast is porous
and absorbent enough to drain very satisfactorily, and hence is not
affected by water except when it is present in great enough quanti­
ties to scour. The principal difficulty with cinder ballast is in
its inability to resist a great crushing or abrasive force, so that the coarser pieces break into smaller fragments and the ballast grinds up and wears out, becoming very dusty, and requiring renewal from time to time. The coarser kind of ashes is found to make an excellent foundation in the case of low moist embankments, the upper finish and surfacing being done with the finer material. The cinder works down into the soft earth beneath, and when ballasted permanently later on, the track is found to have been materially benefitted by the use of the cinder ballast as a temporary expedient. In the case of roads which are poorly supplied with natural sources of ballast, there is great wisdom in husbanding the supply of coarse cinders and making use of them with a definite plan in view. To the end that the men engaged in the work may be stimulated to accomplish the best possible results with the temporary ballast, a definite form of cross-section for the roadbed should be adopted and worked to as rigidly as may be consistent with the time available for such work. In order that the supply of cinder ballast for each track division may be kept upon something of a uniform basis, an account should be kept of the number of cars loaded and the mile numbers where distributed, and those track divisions which do not chance to have within their limits a division or terminal point affording an adequate supply, should receive a share of the cinders from neighboring divisions which have a surplus.
Handling Ballast. The usual methods employed in loading ballast are: (a) by hand shovel; (b) by team and bridge; (c) by conveyor; and (d) by steam shovel. Ballast is unloaded, as a rule, in one of the following ways: (a) by hand shovel; (b) by plow; (c) by trap-car; (d) by dump-car.

The former custom was to load gravel ballast altogether by means of the hand shovel, and the method is still used economically where the quantity of ballast to be loaded is not great, or the depth of the stratum is too small to warrant the use of a steam shovel. The hand shovel is also much used in handling sand and cinder ballast, and owing to its being one of the chief tools required for ordinary track work, there is slight probability that improved methods of loading and unloading ballast will ever entirely supersede the shovel.

Gravel is sometimes loaded on flatcars by teams and scrapers using gangways. Such a plan was employed extensively at the Houston & Texas Central R.R. gravel pit already referred to. In that case, the depth of the gravel bed was too slight to warrant the use of a steam shovel owing to the frequent necessity of shifting the tracks. After some experimenting, the contractor devised a supported gangway on either side of the car, leaving a slight clearance so that the car could be moved ahead without shifting the gangways. By this means, the gravel was handled at little more cost than ordinary
earthwork. One objection to this method was that the cars could not usually be loaded as full as desired, considering the distance to which the material was to be hauled. A somewhat similar device, consisting of a bridge with gangways and having an opening in its floor slightly less in width than an ordinary drag scraper, which is sometimes used to excellent advantage in loading carts and wagons for long haul, would seem to be fairly well adapted to the needs of the case just described, although the additional height required to clear the car and the difficulties in handling the somewhat less portable bridge might cause the latter device to be expensive to operate under the conditions stated.

The ballast from a crusher is always delivered by means of a conveyor, known as the elevator. A bar screen is usually located so as to intercept the screenings and deliver them in the screenings car standing on a track between the ballast track and the crusher, the distance between these tracks being usually 11 ft. The ballast conveyor consists of an ordinary endless belt operated by the same power as the crusher. A similar conveyor is sometimes used in connection with the preparation of slag ballast, and also within recent years, some of the leading Eastern railroads have been using something of the kind in handling cinders.

The development of the steam dredge and shovel within recent years has resulted in a marked reduction in the cost of loading bal-
last. The steam shovel is particularly well adapted to the operation of pits of ballast in which the bed has a considerable depth, the objection to shallow strata being in the loss of time required to shift the tracks and shovel. Careful observation of the use of the steam shovel under varying conditions of material handled and train service, leads to the conclusion that it is pretty certain to cost more than the average manager will anticipate, at least until the cause of the needless expense has been discovered and eliminated. A conservative estimate shows that the cost per day to operate a steam shovel, exclusive of train service, is from $26 to $35, depending upon the nature of the material handled, the depth of the stratum, the skill and experience of the men in charge, and with the make of shovel in particular. The most economical results with the steam shovel are attained when the supply of cars, the train and switching service, and the steam shovel force are consistently balanced, by which is meant that the train and switching service, and the supply of cars, considering the length of haul for the ballast, shall not be so small, on the one hand, that the steam shovel shall be kept waiting for empty cars, and on the other, that the shovel shall not cause a delay in the continued movement of the transportation facilities provided for the ballast. The obstacles to the accomplishment of this ideal adjustment of the two classes of service are so numerous, and their character are clearly understood.
by so few railroad superintendents, that the cost of loading ballast with the steam shovel is in most cases excessive. There are, however, notable exceptions to this statement, for intelligent study of the problem has served to indicate to many of the more progressive managers where the leaks exist in this class of work.

One of the chief causes of the expense is found to be in the fact that few roads are able to own a large number of ballast cars, so that in addition to the available equipment of flatcars, the sides of such coal cars as can be spared are often removed, and thus many cars which have a steady earning capacity are withdrawn from regular traffic, requiring the payment of mileage on foreign cars, unless the road has a surplus of the class of cars so transformed. This difficulty has led to the formation of companies which build and own for the purpose of renting, large numbers of ballast cars of special construction. An instance of such is the Rodger Ballast Car Co., which rents a ballast car of large capacity, costing probably $600, at a rate of about $200 per year.

The great cost of special ballast cars has led to the development of rapid and economical methods for unloading ballast from ordinary cars, the most common and also the best of which is the plow operated by a cable, reference to which will be made below. The form of unloading plow that was first used required a guide timber, about 6 X 8 ins., to be fastened in the center of each car.
These timbers gave trouble by brooming at the ends, thus requiring frequent renewal, and slight variations in the alinement or height of adjoining cars gave much trouble by causing derailments of the plow. An efficient remedy for these evils was secured in the introduction of the Marion improved ballast unloader. This device consists of a plow guided by the ordinary standards of a flat car, and is provided with a front sled-like runner, by which inequalities in the cars cause no inconvenience whatever. The usual method of operating the unloading plow is to attach a long wire cable to the front of the runner, and after setting the brakes of the train of ballast, previously stopped at the point where the material is to be distributed, the other end of the cable is attached to the locomotive which draws the plow through the desired number of cars, and stops with the plow centrally loaded usually on the last car. An ingenious modification of this method was developed a few years ago in an eastern state, where owing to the gravel becoming frozen solid on the cars in cold, wet weather, the train, with brakes set, was slid bodily when an effort was made to operate the plow, the rail being covered with ice. As an experiment, a winding engine attached to a car used ordinarily for wrecking purposes, was set in the train at the opposite end from the car containing the plow; the plow cable was attached to the drum of the engine and by thus throwing the train in compression, the ballast was unloaded without dif-
This device has been placed upon the market and attention has been called to the fact that by running the train at varying speeds in one direction or the other, as the unloading progresses, a greater or less quantity of material may be unloaded. This device is exceedingly well adapted to the filling of water ways, or the extensive widening of embankments.

The use of trap-cars originated in the handling of coal and ore. The side trap was formerly quite common and is still used on many roads. The principal difficulty with this kind of car is in the lost capacity due to the sloping surfaces required to secure automatic unloading of the material.

A center-trap car which has come into quite general use in the West and Southwest, is that made by the Rodger Ballast Car Co., above referred to. This car has the advantage of an unusually large capacity, holding ordinarily 15 cubic yards when level full. The body of the car is hopper-shaped, with a trap consisting of two doors opening laterally at the bottom, and operated by a convenient lever and ratchet at one end. It is essential that the train be in forward motion while the unloading is in progress, in order that the ballast may not drop in a body and clog the train. A car specially provided with a spreading plow beneath is set at the rear of the train, the height of the plow being regulated by means of a vertical screw.
Comparing the side trap car with the Rodger ballast car, it may be said in favor of the former that it does not require the track to be specially prepared, assuming that embankments are wide enough to prevent the ballast from sliding down the slopes, and the track forces are not hindered in the prosecution of their ordinary repairs. The Rodger car, with its large capacity, is unquestionably more economical in the matter of transportation, and in loading there is, perhaps, some saving in the switching service, as compared with the use of cars of ordinary capacity. While the appliances necessary to unload and spread the ballast in the center of the track are more elaborate, involving more expense in the repairs than in the case of the simpler side traps, the Rodger system is certainly the cheaper in the end, provided adequate forces are available for the preparation of the roadbed and putting the ballast in the track without delay.

An instance of the unfortunate use of the Rodger system of unloading ballast occurred on the Gulf, Colorado & Santa Fe R.R. in 1890-2. An extensive contract for crushed rock ballast, already mentioned, had been entered into, and Rodger ballast cars were rented for the work. An order for reduction of forces made it necessary, for the time being, to cease preparing roadbed for unloading. As the crushed rock contract could not be discontinued, it was necessary to proceed with the unloading over a considerable
stretch of track from which the earth filling had not been removed. As a consequence of this injudicious step, the track thus covered could not be repaired properly by the small-sized section gangs allowed, and some of it became quite dangerous, owing to the large number of rotten ties. The final outcome of this mis-use of a good system of handling ballast was a damaged condition of angle plates and rails, the deterioration of quality of a first-class rock ballast by mixing it with soil and clay, and a material increase above the necessary cost of the work if handled as originally intended.

Various forms of side dumping cars have been used. A common form has a vertical-lateral segment at each end of the car, bearing upon a cross-sill, so that the bed of the car may dump by rolling in either direction. An exceedingly efficient side dump car was recently introduced by the Thurston Manufacturing Co. The Thurston car has an air cylinder with a plunger attached to the body of the car in such a manner that the entire trainload may be dumped in an instant by the locomotive engineer, much after the method of applying air brakes.

The most important point to consider in putting ballast into the track is to place the work in the hands of a skilled foreman having a definite knowledge of the local conditions. The latter requirement has been shown to be of special importance by the poor results sometimes secured in putting skilled foremen from the North
in charge of large ballasting forces in the South or Southwest. The few notable exceptions to this rule have been men of sufficient breadth to grasp immediately the differences in local requirements and character of labor in the two parts of the country, and who were thus able to modify methods of work to comply with the changed conditions. Next in importance to the competent supervision of the work is the matter of track tools. Not only is it of the highest moment that the tools should be of good design and quality when purchased, but an adequate and systematic plan for keeping them in repair should be provided and vigorously maintained. The tools of chief importance to a ballasting gang are the shovel, ballast fork, track jack, and hand car.

A strict record should be kept of the numbers and initials and the contents of each car loaded with ballast, of the total number of cars and, as a check on the foregoing, of the particular cars unloaded on each mile, and finally, of the quantity of ballast put in the track and of the length of track finished to standard. These reports should be made up each month in the division engineer's office, being based upon the following reports on regular printed forms: (1) of ballast loaded, by the ballast inspector stationed at the crusher, or by the foreman in charge of the gravel pit as the case may be; (2) of ballast distributed, by the foreman of ballasting gang, or the conductor of the unloading train, or
both as a check; - and (3) of ballast put in track, by the foreman of the ballasting operations. Strict compliance with the standard roadbed drawings should be enforced and grade and line stakes should be set and worked to in all cases.
CROSS-TIES. For many years past the devastation of native forests for the supply of timber for various purposes has been the cause of serious apprehension. With the rapid growth of railroad mileage the demand for timber for cross-ties has become one of the chief items of its consumption. On account of the great scarcity of timber in localities where the native forests have been effaced, and its entire absence in the extensive prairie regions of the West, the length of haul on cross-ties has gradually increased, the cost of transportation in some cases exceeding the first cost of the tie. This evolution has, of course, resulted in enhanced prices except in those cases where the standard of excellence has been lowered to reach the grades of timber which could be supplied at the former prices. Indeed, with a demand so enormous as that which prevails for good cross-ties, it is not surprising that there are very few railroads that have not, for a time at least, been compelled to modify their requirements for this important detail of track construction and maintenance. The construction of railroad lines into fresh timbered regions has from time to time served to relieve the stress of the cross-tie market, and the introduction of improved logging trams has served to prolong the facilities thus

# The writer has in mind in this connection an extensive shipment of yellow cedar ties from Green Bay, Wis., to Galveston, Tex.
afforded. The limit of this process will obviously be reached at
no distant day, for while wooden cross-ties will undoubtedly be
used on a large proportion of the railroad mileage of the United
States for an indefinite period, the use of preservative processes
for timber, which is already claiming the attention of a number of
the more progressive lines of railroad, must sooner or later have
the consideration which its importance demands. It is a most
fortunate phase of the problem that these processes are as a rule
most efficient when applied to certain soft timbers which are not
only comparatively plentiful at the present time, but which may be
replenished within a reasonable period owing to their being of rapid
growth. It is very certain, however, that the demand for timber
must ultimately exceed the supply, so that the solution of the
problem must lie in the use of a substitute for the wooden cross-
tie. Such a substitute is found in the metal tie which is used
very extensively in Europe and which has been introduced to a lim-
ited extent on a few American railroads.

KINDS OF TIMBER. At the present time the most extensive for-
est areas in this country lie within the Southern States. The prin-
cipal varieties of native timber used in the Southwest for cross-
ties are oak, pine and cypress.

Oak Ties. Of the oaks, the white and post varieties are the
most durable, but at best the southern oaks are distinctly inferior
to the corresponding northern varieties, a fact which is doubtless due to the less striking contrast between the summer and winter seasons in the South. The efficient life of a good post or white oak tie under the conditions which prevail in Texas is from 6 to 9 years, depending upon the quality of the tie, kind of ballast, extent of traffic, and severity of seasons during which the tie is in service. Ties made from the red and other inferior varieties of the oak do not, as a rule, last more than 5 years, and owing to their brittleness large numbers of them fail in less than 3 years by breaking in the middle of their length when used in unballasted and center-bound track. On account of its hardness, the oak tie resists the indentation of the rail better and holds the spike more securely than the softer woods above named; but this superiority decreases with the time of service, and after the process of decay has set in the poorer grades of the southern oak tie are found to be no better than the pine or cypress tie in the two important particulars named.

**Pine Ties.** Two varieties of pine grow extensively in eastern Texas and western Louisiana, viz.: the short-leaf and the long-leaf pine. Lumber manufactured from the former of these, known to the trade as "lob-lolly", has a coarse, open grain and is characteristic for its lack of durability when exposed to the elements. The long-leaf pine, on the contrary, is very durable and is used for a varie-
ty of purposes throughout an extensive region. It is used almost exclusively in the Southwest for bridge timber and large numbers of cross-ties are made from it. With those whose experience in track work has been gained in the North, there is a decided prejudice at first against the use of pine ties, but observation shows that a good heart long-leaf pine tie is fully as durable and resists the rail and holds the spike nearly as well as a good southern oak tie. For this reason and because the sawed pine tie is a much more uniform product, it is found to be about as durable on the average as the oak. In the eastern portion of the South where the pine is "boxed" for the purpose of securing the resinous sap, the value of the timber for tie making is asserted to be much reduced. A credible authority who has had ample opportunity to compare the behavior of ties made from the original with those from the boxed pine under like conditions of service, states that while the former "usually rots regularly from the outside, in fact almost wears away," the latter "will rot anywhere, one end sometimes being good and the other worthless, and will often have the appearance of being sound and at the same time be so rotten as not to be able to hold a spike." The short-leaf pine, owing to the exceedingly coarse and open character of its grain, is well adapted to the use of preservative processes and there is reason to anticipate that the steps already taken by several Southern and Southwestern railway systems
to utilize the timber for this purpose will be largely extended in the immediate future.

**Cypress Ties.** The cypress timber from which ties are made, prevails in plentiful quantity in Louisiana and other states to the eastward along the Gulf coast. The characteristic feature of cypress timber is its durability in moist places and it is this quality which has led to its extensive use in the construction of wooden tanks. Being quite soft, cypress does not well resist the crushing tendency of the rail and consequently is not well adapted for use as cross-tie timber under heavy traffic, particularly on curves. However, in low-lying and moist localities where other kinds of timber are subject to quick destruction from dry rot, the cypress possesses unquestioned advantages which are widely recognized by experienced trackmen.

**Decay of Timber.** In this connection it is of much importance and interest to comment upon the characteristic manner in which timber used for cross-ties and other exposed purposes, fails by decay under the severe conditions of dryness and moisture in the Southwest. As a rule the tie is more or less green when put into service, and since most of the tie is buried, only that portion which is in contact with the direct atmospheric influences becomes seasoned to an appreciable extent. Decay sets in on the interior of the tie and the concealed portion often crumbles away in course
of time without exterior evidence of the fact. The seasoned outside shell, usually a quarter-inch or so in thickness, often retains its original firm texture and sharply defined edges up to the time that a shovel is needed in removing the fragments of the decayed heart in renewing the tie. Many skilled trackmen and bridge carpenters whose experience has been gained in the North, are slow to appreciate the phenomenon just described, so that they are inclined to place too much confidence in treacherous track or bridges, and to accuse subordinates of extravagance in the matter of renewals. Such misapprehensions on the part of a newly appointed official may be quickly dispelled by spending a brief period with section gangs in tie renewals or with bridge gangs on deck renewals, or by a thorough and conscientious hand-car inspection trip. Reference to the phenomena above described will again be made in discussing bridge standards and renewals.

Tie Accounts and Records. A strict account should be kept in the office of the division engineer of all ties received, distributed, and put in the track each month. To this end, the section foremen must be required to make, on specially prepared blanks, monthly statements to the division roadmasters covering the following items:

(1) Number of ties on hand last day of preceding month.
(2) Received during current month.
(3) In account
In order that the section foreman may keep this important account correct, the printed blank should contain instructions about as follows:

(a) Preserve duplicate copy of report for future reference.
(b) When ties are received, count them and record number promptly.
(c) Keep a careful daily account of the number of ties put in track.
(d) Report by actual count the number of ties on hand the last day of month.
(e) The "rotten tie" account will be based upon semi-annual enumerations made by the section foreman in person. These enumerations will be made during the last week of the months of March and September, so as to embody the revised count in tie statements of April and October, respectively. A tie will be classed as "rotten" when it should be renewed within a period of six months.

The report above outlined is sent to the division roadmaster, who transcribes the numbers to a form having like headings, and after verifying the report by comparison with preceding statements and such records of ties received as he may have in his office, sends it to the division engineer. The latter officer makes a similar transcript and verification and forwards the summarized tie statement to the office of the engineer of maintenance of way, where a summary of the tie account for the entire road is made up in connection with the cost of handling ties on each division.

Much good is found to result from a comparison of the total number
of ties put in track and the cost per tie for putting in on the several track divisions and the comparison may often be carried to the sections themselves with profit.

Spacing of Ties. The number of ties per mile should be about 3,000, which is equivalent to about 17 to the 30-ft. rail. This number of ties gives an average spacing of close to 21 ins. center to center, which leaves ample room for the insertion of the shovel between adjacent ties in track work. It is of the first importance that the ties should be spaced with uniformity, except in possible cases of unballasted track having decided fluctuations in the character of the soil. All such cases of irregularity should be looked upon as emergencies, and temporary ballast should be provided so as to restore the proper spacing of the ties at the earliest practicable opportunity. While theoretically it would seem desirable to have a solid floor of ties, the necessity above referred to of inserting the shovel freely between and beneath the ties, must have due consideration.
RAILS. Steel has so far replaced wrought iron as a material for the construction of T-rails that it is now exceedingly rare that an order for iron rails is placed. In fact, but few concerns in the country are at the present time equipped to fill an order for iron rails. This revolution was the immediate outgrowth of the introduction of the Bessemer process of manufacturing steel, the first important use of the product being in the manufacture of rails. At first, some difficulty was experienced in securing uniformity in the steel, but owing to the stimulating effect of the great demand for first-class rails to take the place of wrought iron which had begun to show marked signs of retrogression, the process was rapidly perfected and also cheapened, until, at the present time, the cost of producing first-class steel rails is less than that of the same grade of wrought iron rails. It has not been many years, however, since iron was used extensively for this purpose, and most roads still have to contend with a relic of the past in the form of repairs to wrought iron rail which has not been relaid with steel, or which has been shifted to some branch line, or to side track service, after having been replaced by steel rail on the main line. Except for this fact, there would be no necessity for discussing wrought iron rails.

Wrought Iron Rails. High grade in the quality of wrought iron rails depends both upon the quality of the iron used and the care
and skill exercised in piling the metal in the process of manufacture. The wrought iron rails imported from England many years ago fairly won a high place in the estimation of those who had the opportunity to observe their behavior. An instance of such rail is still to be found on a portion of the Montgomery branch of the Gulf, Colorado & Santa Fe R.R. This rail weighed but 40 lbs. per yard when first laid about 1878, and it has worn so uniformly, for the most part, that actual weight of unbattered rails in 1891 showed that the section had been reduced about 12 1/2%; the grades are as much as 90 ft. per mile in places, the line having been built with a view to cheapness, and the traffic, consisting mostly of lumber, has been quite heavy. Had the vertical stiffness of the rail been greater, or had the ties been used in more generous numbers, there is little doubt that this rail would have lasted as long as much of the steel rail which is put on the market at the present time.

**Repairs to Wrought Iron Rails.** One of the most unsatisfactory features of track work is found in the repair to iron rail when used on main track, especially when the track is not adequately ballasted and the attention of the section gang should properly be given to other details of the track work. When wrought iron rail has reached that stage in its career when the head becomes battered at the joints and laminated at intermediate spots, it is exceedingly difficult for the most industrious foreman, supported by a liberal
sized gang of good laborers, to make anything like distinct progress in improving the condition of his section. It is very important that such a section should be amply supplied with enough good rails, distributed so as to be convenient for use where most needed, so that the time of the gang may not be wasted in trucking rails great distances. This point is of particular importance when the track is softened by rain or by the frost leaving the ground, and the danger from broken rails or splices is multiplied. A few good rails should be reserved for use in case of a wreck or washout, and these rails should be piled at the section house so as to be loaded without waste of time in case a wrecking train, requiring such rail, should stop in the night to take on the gang.

It is especially important that the chisels and punches, used in this work, be kept in first-class order, and that gangs having poor rail to contend with should not be stinted in the supply of such tools. In case of a rush, such as is often required in bad weather to keep trains running on such rail, extra help should be allowed, and due consideration should be given to the necessary neglect of matters of surface and line and other routine features of the track work. Occasionally, it may be necessary to borrow neighboring gangs for the purpose of catching up on the rail repairs of a particularly dangerous section; and where small forces are allowed, it may often be necessary for the gangs to work Sundays when
the reduced number of trains affords a better and safer opportunity to make repairs. It is obviously slow work for a gang of four men to handle a 30-ft. rail when two of them are required frequently to flag against approaching trains. In reality, the necessities of the work often make it impossible to spare the men for flagging duty, and it is quite common to take chances on stopping trains by simply setting out a flag in each direction. A particularly embarrassing emergency with a small gang of men occurs on sections where long and narrow cuts are common, and it is necessary to truck rails considerable distances. The flagmen are an absolute necessity in such a case, and the danger of not being able to get the rails unloaded and push car removed from the track in time for approaching trains is much increased by the tendency of some locomotive engineers not to give proper heed to the trackman's flag.

Mill Iron. It is very desirable to clean up the worn out rail from time to time and sell it as mill iron. In order that an approximate idea may be had at headquarters as to the quantity of such rail available for shipment, a set of rail reports are essential. Following are the essential points to be embodied in these rail reports:

(1) Lin. ft. good rail on hand last day of preceding month.
(2) " " " received during current month.
(3) " " " in account " " "
The foreman is enjoined to keep close track of the rail account, since it is the basis of the summarized statements from the division roadmaster to the division engineer, and from the latter officer to the engineer of maintenance of way. Foremen of sections having iron rails should have standing instructions to follow as strictly as possible the plan of assorting the rail with the current work, in order to avoid handling it an unnecessary number of times. The best plan is to assort the rail into three classes, viz.: (1) that which is entirely worn out and properly classed as mill rail, (2) that which may be culled so as to save pieces as long as 12 ft. or so; and (3) that which is fit to use in the track again. As time can be spared for the work, or as the necessities of rail repairs demand, the second class should be cut into the other two, so that in case of a sudden order for a shipment of mill rail, no time will have to be taken from the work, perhaps at a critical period, for the purpose of assorting the rail. Foremen should be given to un-
derstand the value of system in such work, and they should be re-
quired to observe neatness in piling rails. When the iron rail is
finally relaid with steel, a sufficient supply of good iron rails
should be retained for the repair of sidings provided, steel rail
is not laid on them as well.

**Steel Rails.** As already stated, nearly all rails are made at
the present time from Bessemer steel. This material is found to be
admireably adapted to the service thus imposed upon it, provided due
care is taken in the selection of the pig from which it is made,
and in perfecting the chemical and physical nature of the product.
The steel rails put upon the market by most of the reputable rail
mills are found to render excellent service. The two principal de-
facts in steel rails are a tendency to brittleness and the existence
of soft spots. The former of these evils reveals itself in the form
of broken rails, and since such accidents occur most frequently in
cold weather, it is common to assign the difficulty to cold short-
ness resulting from an excess of phosphorus. The existence of soft
spots is shown by the excessive local wear of the rail. The diffi-
culty is sometimes assigned to the inordinate slipping of the driv-
ing wheels, a habit to which some locomotive drivers are addicted.
While the worn spots perhaps frequently do not appear until such
slipping has taken place, the explanation is not sufficient to ac-
count for the evil as a whole; for a careful examination of places
where slipping is very common, will often show many rails that are not so battered in the least. The existence of soft spots is usually assigned to the defective working of the steel in the process of manufacture, and it is probably independent of the chemical constitution of the metal.

**Rail Sections.** Much study and investigation has been given to the design of rail sections by some of the best authorities identified with railroad and steel making interests. The most elaborate inquiry yet made was that conducted under the direction of a special committee of the American Society of Civil Engineers a few years ago. A previous committee of the same society had investigated the proper relation between the form of the wheel and the rail head, and the later committee had the benefit of the light thus thrown upon the subject. It was found difficult to decide upon fixed cross-sections for the various weights of rail, but a series of recommendations were made by the committee, which are believed to embody proper principles both as regards the manufacture of the rail and its service in the track. These recommendations are as follows:

1. A 12-in. top radius as a standard for rail sections of all weights.
2. A broad head, relatively to depth, for sections of all weights taking care not to go so far in either dimension, especially in very large or very small sections, as to endanger the flange cutting into the joint.
3. A 1/4-in. corner radius as a standard for sections of all weights.
4. A 1/16-in. lower corner radius for the head, as a standard for
sections of all weights.

(5) That starting from a sufficient base width of head to give am­ple bearing for the joint or to conform to recommendation (1), the sides be carried up vertical, as a standard for sections of all weights.

Although many high authorities have much faith in the wisdom of these recommendations, they have not been sufficiently tested to warrant their final adoption. It is, of course, desirable to consider the subject as open for continuous investigation, and no doubt these recommendations will be supplemented or modified in the light of further data acquired from the service rendered by rail rolled to comply with the principles above enunciated. The action taken by the eminent society named gives cause for gratification, for there is no hope of securing anything like uniformity of practice in this matter except through the united action of leaders in the profession most concerned in the results. It has hitherto been quite common practice for the best mills to roll their standard sections for the general market in accordance with the standards re­quired by the Pennsylvania or other leading railroads. For this reason, the question of form of cross-section of the rail has never been given serious consideration on many smaller roads, the results obtained from the rail as purchased in the open market being satis­factory.

Laying Steel Rail. It has heretofore been the practice of many railroads to lay iron or second-class steel rails on first construc-
tion, because of the belief that good steel rails would become sur-
face bent by the excessive local settlement of the new embankments.
In the course of a few years, after the roadbed becomes firm and
the worst sags have been removed, it is the usual custom to relay
the original rail with new steel rail, provided the traffic and fi-
nancial condition of the road permit it. The various steps in-
volved in such work are as follows:

The steel rail and angle bars are carefully distributed, much
care being taken not to bend any of the rails in removing them from
the cars. After providing a sufficient supply of track bolts, the
outside spikes are drawn, and the old rails are thrown outward in a
string by means of lining bars, without removing the splices. If
necessary, the rougher places on the ties are adzed down so as to
afford a good bearing, and the new rails are laid in place, one at
a time, being handled best by means of rail tongs. Expansion shims
of suitable thickness are used to procure the needed space between
the adjacent rails, and the new angle bars are bolted on immediate-
ly and the joint is set as tight as necessary. The ties at the
joint are shifted, if necessary, and the rail and angle bar slots
are full spiked. A pair of split or point rails is kept constantly
at hand on a push car, and when the approach of trains, or the end
of the day's work demands that the old and new rails be connected,
the heels of the point rails are bolted to the ends of the new
rails, the old rail being lined to correspond to the stock rail of a split switch. The following organization is about right for laying complete one mile of steel rail without delaying trains unnecessarily:

1 general foreman.
1 assistant 
6 men drawing spikes.
4 # throwing out old rails.
4 # adzing ties for new rail.
8 # carrying rails.
1 # adjusting expansion shims.
1 # holding rail against spikes.
6 # spiking.
1 # drawing spikes for new joints.
1 # adzing ties for new joints.
12 # putting on angle plates.
2 # carrying water.
2 # flagging.
50 #

Another method of relaying rail consists in connecting up the new rail in strings and throwing it into place. The principal objections to this method are that the spacing of the rails is disturbed in shifting the string laterally with the lining bars, and that the danger of delaying trains is much greater than with the simpler plan of putting one new rail into place at a time. It is of the first importance that the joints should be put in good order as a part of the work of laying the new rail. The plan of having an extra gang follow the laying gang for the purpose of surfacing the track is an excellent one, but the care of the joints should not be left to this gang.
Rail Joints. The rail joint problem has been the cause of much experimentation and discussion. It is scarcely necessary to detail the well-known evolution of the rail joint from the primitive chair, through the various stages of the fish plate, sampson bar, and angle bar, nor to attempt to describe in detail the many patented joints which are in the experimental stage at the present time. Most railroads are making tests on a more or less extensive scale of one or more kinds of joints, and there is some hope of promoting the status of this important matter if high authorities can come to some agreement. By far the most prevalent type of joint in the United States is the angle bar joint, variations being effected in it by modifying the cross-section and length of the angle bar, and the number of track bolts employed. For a number of years after its introduction, it was nearly universal practice to use only four bolts to the joint, but a few years since, the use of longer angle plates, having six bolt holes, became quite common on many roads. Recent inquiry, however, seems to indicate that there is a tendency on a number of first class roads to return to the use of the four-bolt joint. The reason for this later tendency is not stated, but it is fair to assume that, if warranted, the reasons have originated in close observation into the relative first cost of the two joints in connection with the expense of maintaining them. The primary argument urged in favor of the six-bolt joint was the reduced cost.
of maintaining it. Those who opposed the longer angle bar, pointed out the fact that in some respects the more expensive joint might actually cost more to keep it in first-class order, and the question was asked, "if six bolts, why not eight?" "if eight, why not ten?", or, passing to the limit, "why not have the angle plate extend the full length of the rail?" These questions were, of course, put by extremists, but it must be admitted that the arguments in favor of the four-bolt joint are strong enough to demand that it shall not generally be replaced by the six-bolt joint without the establishment of the fact that the change will result in a material saving in track maintenance.

Suspension vs. Supported Joints. The relative advantages of the suspended and supported joints are frequently set forth, although the subject is not so generally discussed now as in former years. Most roads have adopted one or the other of the methods and adhere strictly to it, although the more progressive lines have in use some of each kind as an experiment. Those who urge the use of the suspended joint, claim that it makes the track more elastic, and hence rides easier, than the supported joint. The others make the assertion that the supported joint is more cheaply and certainly kept in repair because of the tie being placed at the weakest point of the track, and that, as a whole, the riding qualities are superior to that afforded by the other class of joint. As a matter
of fact, if either were distinctly superior to the other, observation of the tendencies of the American railroad management to adopt improved methods leads to the belief that the better of the two would be almost universally employed. On poorly ballasted track, where the joint is particularly at a disadvantage owing to the insufficient and fluctuating character of the roadbed, particularly in wet seasons, the use of a liberal-sized joint tie is unquestionably wise, and under these unfavorable conditions, the supported joint seems fairly to deserve preference. But where the track is well ballasted and maintained in a proper manner, it is exceedingly doubtful if either type of joint has an advantage which is not offset by one of another kind possessed by the other.

**Broken vs Square Joints.** The statement just made in relation to the arrangement of the ties at the rail joint, are essentially applicable to the two methods of arranging joints in the two lines of rail with relation to each other. Theoretically, the broken joint is obviously superior, the principle involved being embodied in all good construction work. But other considerations have been found to modify the application of this principle in the case of railroad track. The chief argument in favor of square joints is found in the case of poorly ballasted or maintained roads, where the torsion to rolling stock is materially reduced and the comfort of travel is claimed to be improved by the use of the square joint.
However, as above intimated, there is no reason to believe that either is distinctly better than the other in case the track is well ballasted and cared for. It is a somewhat curious fact that the broken joint is most used east of Chicago and the square joint prevails most commonly on Western lines.

**Track Bolts and Nutlocks.** Much money is wasted in purchasing track bolts of a cheap grade. A standard make and size of bolts should be adopted and adhered to, as it will much simplify the matter of bolt repairs. Certain patent bolts have been used quite extensively in connection with relaying rail. One of the best of these, the Harvey grip bolt, is claimed to do away with the necessity of using nutlocks, but this claim is not warranted by experience under the ordinary conditions of track work, and it is much wiser to look upon the Harvey bolt as superior only because of the mechanical excellence of the thread upon which basis alone, it is a paying investment.

One of the earliest successful nutlocks was the Verona, which consists of a single turn spiral spring made of the best spring steel, and having the edge in contact with the nut and the splice made chisel shape so as to add to the holding friction. The Verona has been copied by several more recent nutlocks, notably by the National, the original patent on the form having expired. The Verona type of nutlock possesses the advantage of protecting the thread of
the bolt for 1/4 in. or so, making it possible to tighten the nut after the bolt has worn or jarred loose; and with the spring action, the process of unscrewing with the constant jar, is much delayed. Owing to the fact that a track bolt can never be set up so tight at first but that there will be a slight looseness after the angle bars have come to a final bearing against the head and flange of the rail, it is often of the first importance that the nutlock should not interfere with a readjustment of the bolts in a short time after the rail is laid. The various forms of rigid nutlocks are not, as a rule, susceptible of this after adjustment, and hence they are not well adapted for use on track bolts. An ordinary ring washer serves very well as a nutlock, especially when combined with a ring of elastic fiber, as in the case of several devices which are on the market at the present time. Likewise, strips of hard wood, with holes bored to match the bolt holes, have been used with considerable satisfaction, although the life of such a devise is necessarily not great. Other nutlocks, such as the Excelsior, are made to lock two bolts at once, but this plan is liable to prove defective by the breakage of one of the bolts thus paired. It may be stated as a general principle that a nutlock can not prove entirely satisfactory from a practical stand-point, unless it is simple in application, cheap in first cost and maintenance, possesses the elastic feature, and serves to protect a short stretch of thread for use in tighten-
ing the bolt.
SPIKES. The standard track spike, 9/16 X 5 ins., which is in common use on most roads is a successful means of fastening the rail to the wooden tie, and owing to the cheapness and simplicity of its application, there is very slight probability that it will be superseded, at least for many years to come. The ordinary spike is not a firm means of holding the rail after the tie is affected by decay, but it is not claimed that any device for this purpose can prove entirely satisfactory after the wood becomes weakened. Various appliances have been proposed as a substitute for the common spike, but most of them are open to criticism because of their complicated nature, and on account of the fact that they would require a higher grade of skill in their application than can be expected from the track labor used on most roads. A few devices, such as the Busk interlocking bolt, are well adapted to the needs of elevated roads, where skilled track labor is usually employed, but there is no reason to anticipate that they will ever be generally adopted. Various special forms of the spike have been introduced of late, which claim to damage the tie less, and to have a greater holding power than the common spike. While these advantages have been proven experimentally in most instances, there is some reason to doubt the efficiency of the improved spikes after the tie begins to decay. On the whole, however, there seems much more promise of a develop-
ment in this important detail of track construction through the mod-
ification of the form of the ordinary spike, than in the adoption
of a less simple form of fastening.
TIE PLATES AND RAIL BRACES. The cutting into ties by the base of the rail early led to the use of plates for the purpose of securing greater area for transmitting the rail pressures to the tie. It was soon found that a simple plate became loose and the device proved to be noisy to an annoying degree. This led to improvements by which the plate would not become loose. The most successful of the tie plates now in use is the Servis tie plate, which is U-shaped in section, the two projecting edges being hatchet-like in form so as to cut into the tie. It is claimed that the Servis tie plate is a complete success, the life of the tie, particularly when of soft wood, being materially prolonged by its use. Instead of the projecting edges injuring the tie, as some have charged, the makers of the Servis plate claim that the tie is actually benefitted through the compression of the wood fibers, owing to the wedge form of the indenting edge, the passage of water into the tie being thus retarded. The tie plate has spike holes punched in it, and it is believed that the holding power of the spike is much increased thereby, and that consequently, the tie plate serves to reduce very materially the danger of spreading track and overturning rails. Where soft ties are employed, there is little doubt that the Servis tie plate is a paying investment, particularly on curves, and its use is certain to show saving in the cost of tie renewals.
The rail brace is mostly used to prevent the overturning of rails on curves or, in general, where there is an excessive lateral or overturning pressure to be overcome. The rail brace was formerly made of cast iron, but that style has now been replaced very largely by pressed steel braces, which are capable of withstanding no small amount of distortion without breaking. The Ajax brace which is used perhaps more extensively than any other, is an example of a first-class rail brace of the improved type. From one to three braces are used to the rail length on turnouts and other sharp curves, and, as a rule, two of them are used to stiffen each guard rail to a switch. A special form of the guard rail brace, manufactured by the Morden Frog and Switch Co., has a hook or jaw which grips beneath and onto the opposite side of the flange of the main track rail. This device is claimed to be a decided improvement over the ordinary form.
SWITCHES AND YARDS. The construction of switches and yards should, as a rule, be placed in the hands of experienced foremen, who appreciate the importance of working closely to stakes set by the engineering department of the road. Comparatively few foremen have a proper understanding of the relation of frog number to length of lead, and it is not uncommon to find intelligent trackmen referring to the number of the frog simply as its length in feet. This error no doubt grew out of the custom adopted many years ago by the Elliott Frog Co., of East St. Louis, Ill., of making the number of feet in length equal to the number of the frog. Another common mistake made by foremen not used to working to an engineer’s stakes, is setting the end of the frog intended for the point of the frog at the stake. While it is a fact that the length of lead may be varied a foot or two from the theoretical length without injuring the appearance or the operating value of the turnout, it is not wise to give the foreman much margin in the matter. This is particularly true of the construction of a systematic yard, where the slightest variation from the specified points, particularly on the ladder or lead tracks, may be clearly visible and result in an eyesore that can not be easily remedied.

The repair and general maintenance of switches requires close attention from a foreman with experience in this line of work. Con-
siderable care should therefore be exercised by the division road-master in selecting foremen to take charge of important yards. Usually many outside matters are imposed upon track gangs located at extensive division or terminal points, and it is important that the foreman should be a man above the average in business judgment. It is not infrequently the case that men in such positions are promoted to the position of division roadmaster, owing to the more or less conspicuous character of their work. It is a wise policy to have it understood that the position of yard foreman is one of special responsibility and to make it a prize by paying a somewhat greater salary.

Switch Material. It does not pay to purchase cheap frogs and switches. The best quality to be had in the market should be procured. If the stub switch is used, it pays to procure the Cooper or other wrought headchair, instead of using the old style cast iron chair which is so easily broken. The old form of vertical switch stand should give place to a good substantial horizontal stand, so constructed that it can not wear and become loose enough to make the operation of the switch unsafe. The danger from such looseness is much greater in the case of the point switch than with the stub, although the formation of a lip in the latter is the source of much annoyance on roads which have not entirely discarded the stub switch. If the split switch is used, it is believed to be better
to adopt straight points, instead of attempting to keep a stock of right and left hand points. The standard length of 15 ft. should be adopted, since it has been shown to give most efficient service under all conditions. In specially cramped positions, however, shorter points may be used, a length of 7 1/2 ft. being employed for such cases on some roads. Likewise, it may occasionally be necessary to use a very flat turnout, at a junction, for instance, and in this case the use of 18-ft. switch points may be justified. Should this be done, the points should be ordered in duplicate and the extra points be kept close at hand, so that no delay to traffic would result from the breakage of points of unusual length.
CROSSING FROGS. The railroad crossing frog is an unsolved problem in track maintenance. Nominally, each pair of wheels deals two blows in passing over a crossing frog, but this is not strictly true unless the angle of the crossing is practically a right angle. In the case of an oblique angled crossing, each wheel delivers two blows, so that eight blows result from a four-wheeled truck and twelve blows from a six-wheeled truck. Thus a car supported by two four-wheeled trucks may deliver to a crossing frog sixteen distinct strokes or impulses, and the number received from a heavy sleeping car with six-wheeled trucks is twenty four. When the car moves slowly over the crossing, the blows are distinct, but as the speed increases, the wheels do not have time to drop into the breaks of the rails, and the effect becomes more of the character of a continuous shaking or vibration. In either case the destructive effect upon the frog is very marked, and at best the crossing frog is a short lived device. Under the heavy traffic which is common on many crossings in large cities like Chicago, it is quite often necessary to renew frogs after they have been in service only three months. It should be noticed, however, that the standard of quality in such a location is necessarily higher than with less crowded traffic, so that a frog which might render service very satisfactorily under ordinary conditions would properly be regarded as dangerous under the more severe requirements of a heavy suburban traffic.
The durability of the crossing frog depends in a great degree upon the care with which the supporting timbers are put in and subsequently maintained. Some good trackmen believe it is best to frame the crossing timbers together, but the tendency seems to be more in the direction of using timbers similar to those employed in the construction of switches. The framed timbers are quite satisfactory, as a rule, until decay begins, after which it is very difficult to maintain the crossing. The tie timbers, on the other hand, are cheaper to begin with, are more economically kept up, and when decay begins, they can be renewed singly, if desired. It is believed to be wise practice to use plates under the rail intersections in order to prevent the base of the rail from cutting into the wood. The plates also serve to stiffen the weakest places in the frog, which, unfortunately, are also the points receiving the most severe blows by the passing wheels. Reference has been made in another place to the need of extreme care on the part of the engineer in obtaining the data to accompany the order for a crossing frog, and also to the treatment of this subject in detail which is presented in Appendix II.
TRACK WORK. The essential requirements of good track are permanently good line and surface. These are made possible only by the use of rails, cross-ties and ballast of good quality, and by observing proper methods in the various features of track maintenance.

Line. Defects of alinement in the track are more easily discovered by an ordinary observer than are vertical undulations of a minor kind. For this reason, it is customary for track foremen to devote an undue share of their attention to perfecting the line. Errors of line on tangents are, of course, much easier to detect than those on curves, so that the latter are not, as a rule, given the time that they should have. Sudden swings from the true line have the effect to tilt the car and give a side lurch which is very disagreeable. If the track is not well ballasted, this sidewise blow acts to throw it still further out of line, or to extend the defect to another point immediately adjoining the first. Since the same effect is produced, though in a less degree, with well ballasted track, it is of the utmost importance that minor defects of line should not be neglected.

The best manner to preserve the line of the track after it has once been perfected, is by the use of an ample filling for the track. With rock ballast, a 6-in. shoulder outside the ends of the ties is common. With gravel and other kinds of ballast which are
not porous enough to admit of a flat top, it is often necessary to give drainage by running the lateral slope line through the bottom of the end of the tie. In this case, the lateral stability in the superstructure afforded by the ballast is limited by the frictional hold on the tie, and such track retains its line much less permanently than track with heavy shouldered ballast. On tangents there is usually no great difficulty in lining track, provided a good general line was originally established instrumentally, but far too many foremen lack the ability to line even a tangent satisfactorily. If the general line of the tangent is poor, it is essential that the foreman should have had much previous experience in this kind of work to accomplish good results.

It is found that most trackmen have a tendency to line curved track outward, and this practice often gives no inconsiderable amount of trouble to the engineer engaged in the readjustment of the alignment, owing to the widening of old embankments thus necessitated. The fact that the foreman is held responsible for the riding qualities of the track, has led him to consider the best practical manner of relieving the train of the lurch due to the sudden change of direction at the ends of curves. Skillful foremen accomplish a marked improvement in the riding quality of simple curves by flattening the rate of curvature for a couple of hundred feet at the ends. This requires a sharpening of the curvature for a short dis-
tance beyond, but on the whole, this second evil is much less than that which has been removed. This very common custom with good foremen furnishes the wisdom is using suitable transition curves on first construction, and there does not seem to be any substantial reason why such curves should not then be laid out. Furthermore, while the expense of introducing transition curves is usually quite considerable on old roadbeds, the value of the results is sufficient in a majority of cases to warrant the expense, particularly since it is asserted on good authority that with the average case of old embankment, the curve with transition ends is no more expensive to establish than a continuous simple curve.

Surface. As above stated, defects of line are much more evident than those of surface. It is desirable that continuous grades should be established and maintained, but it is found that the riding qualities of track are affected much less by local undulations of grade line which are followed alike by the two rails, than by differences in elevation in the opposite rails on tangents or by improper variations in the rate of super-elevation on curves. Fluctuations of the latter kind depend, for the most part, upon the proper use of the track level. Probably no other track tool having anything like the intrinsic worth, is ever neglected to the extent which is common with the level. The relation between surface and line of the track, already alluded to, is made evident by studying
the effect upon a moving train of a difference of elevation in the
two rails at opposite points on straight track. Such a difference
in elevation causes a lateral movement of the center of gravity of
the car, and the momentum due to this movement is transmitted to the
rails and the track is shifted out of line. It is probable that
most defects in line originate by this means, and that they may be
multiplied indefinitely in the same manner, resulting finally in a
flaw sufficient to cause a derailment.

Reference has already been made to the superiority of square
over broken joints on poorly ballasted track, owing to the reduced
liability to unsymmetrical settlements of the track. This fact is
verified to a marked degree on branch lines on many Western roads,
where the prevalence of soil poorly adapted to the construction of
a desirable roadbed, together with the absence of ballasting materi­
al, sometimes lead to a shockingly bad condition of the track at
certain seasons of the year. In such a case, it is necessary and
entirely justifiable to suspend, for the time being, all efforts to
do work according to adopted standards, and to confine the attention
of track forces to keeping the track in such condition that trains
may be kept running.

**Super-elevation of Curves.** Much thought and discussion have
been devoted to the determination of the precise amount of super­
elevation required for specified degrees of curve and rates of train
speed. It should be understood, however, and particularly by the foreman who is responsible for the riding qualities of the curve, that the precise amount of the super-elevation given to the outer rail is relatively much less important than that the super-elevation should be kept uniform. A failure to comply with the latter requirement reveals itself in a characteristic rolling motion, which is both disagreeable to the passenger and destructive to rolling stock. In deciding upon the proper rate of super-elevation, the writer has come to the conclusion that fixed rules are to be followed only in a general way, and that on roads having a profile of a distinctly undulating character, by far the best and safest plan is to study the position of the curve with relation to local grade line and its effect on the speed of trains. This plan was tested by the writer, and the judgment above expressed was fully confirmed, in the process of laying ballast grade lines over a stretch of some 40 miles of undulating country in the Southwest a few years ago. Ordinarily, the rate of super-elevation already in use in the unballasted track was taken as a definite basis for that in the newly ballasted track. Occasionally the old curve was in such bad order, or the rate of super-elevation seemed so excessive, that the new rate would not be finally settled upon until careful inquiry could be made among the more trustworthy freight and passenger locomotive engineers in relation to the riding qualities of the curve in ques-
tion. In exceptionally important cases, or when the evidence was conflicting, one or more trips would be taken over the curve on a locomotive. As an instance of the results sometimes attained by the use of the plan just described, the writer recalls a one-degree curve at the foot of two long grades on which he found an average of 1 1/2 ins. of super-elevation before ballasting. As the speed of trains was nominally 25 miles per hour, and the super-elevation for that speed would be only one third of the amount in use at the time, a careful inquiry was made and special trips were taken over the curve on a locomotive, with the result that the full amount named was used. In this particular case, the writer has believed that he saw the effect of an abnormal coefficient of friction between the tread and flange of the wheel and the top and side of the rail head owing to the local prevalence of an exceedingly fine and sharp sand. In dry weather, this sand rises profusely with the passage of each train, and it must in some degree affect the normal friction between the two burnished metal surfaces. The writer has not seen this condition discussed, but in adopting a rate of super-elevation so much in excess of that which would be required under ordinary conditions, he sought to support his action by an analysis of local conditions. The maximum speed attained by fast trains on the curve under consideration was probably not much above forty miles per hour, for which the rules usually proposed would demand a super-elevation of about
In the case of curves at summits or intermediate points on long grades, where the speed of heavy freight trains may be reduced in one or both directions, it may be necessary to adopt a compromise rate of super-elevation, inasmuch as excessive super-elevation has the effect to increase curve resistance and thus to decrease the number of cars to be hauled in the train.

Routine Track Work. No attempt will here be made to describe in detail the many duties which devolve upon the track forces aside from those already enumerated. In general, it may be stated that the section gang attends to all matters more or less directly connected with the maintenance of the track, and also such minor details as repairs to fences, etc., which are most economically handled by a force of men passing daily over the road. Nor does it seem desirable to present here a set of rules for the government of section foremen and laborers, since many features of such rules necessarily depend upon local conditions varying widely even with different roads in the same locality.

It is pertinent to say in conclusion that the successful administration of the track department will depend very largely upon the extent to which the division roadmaster succeeds in training his forces to have a proper regard for the element of true economy in the work assigned to their care, without losing sight of the equally important matter of being always efficient; in other words,
let those who are responsible for tangible results be made to understand that true economy involves doing the work well. Again, it is very certain that entire success can not be realized except by the use of systematic methods of work; and with track work, a part, at least, of the system must consist of cleanliness and neatness. Referring to the character of the men engaged in the track service, it may be asserted as a well established principle that good roadmasters means good foremen, and likewise good foremen means sober, industrious laborers. In general, it may be stated that the section gang attends to all matters more or less directly connected with the maintenance of the track, and also such minor details as rails, ties, spikes, etc., which are most economically attended to in a form of men passing daily over the road. Nor does it seem desirable to present here a set of rules for the government of such expert and efficient workmen in such duties other than laborers; since many features of such rules naturally depend upon local conditions varying widely even with different roads in the same locality.

It is pertinent to say in conclusion that the successful and economical management of the track, in any of the circumstances, introduction of the branch department will depend very largely upon the extent to which the division roadmaster succeeds in training his men to have a proper regard for the element of true economy in the work assigned to their care, without losing sight of the importance of other matters equally essential in the work done by him.
BRIDGES AND BUILDINGS DEPARTMENT.

OFFICERS. Bridgemaster. The division bridgemaster should be a man of sound judgment, cool temperament, and sober habits, with a thorough and practical knowledge of the work pertaining to the bridges and buildings department, and having the requisite tact to direct the operations of the forces engaged in the service of that department. Almost invariably the division bridgemaster is a man who has had experience as a bridge carpenter and has filled in a more or less creditable manner the position of foreman. The bridgemaster should possess the ability to handle the routine duties of his position in a vigorous and business-like manner, and in cases of washout, wreck, or other emergency involving structures coming under his care, he should be able to direct the movements of available forces and materials in a cool and reliable manner. He should be a good judge of men in order that his foremen and carpenters may be of desirable quality, and of materials so that he may be of direct assistance in maintaining the standard of quality of timber and other construction material. In view of the wide variety of matters arising in the administration of the maintenance of way department, which are not particularly connected with the work of any particular division of the service but are most frequently assigned to the case of the bridgemaster, it is essential that he should be constantly
on the alert for information that may be of use in carrying into execution any project that may demand his attention.

**Foreman of Bridge Gang.** The foreman of a gang of bridge carpenters should be a successful carpenter himself, who has won preference by his ability to manage men and work advantageously. He should be indefatigably industrious, and should be constantly on the lookout for opportunities to excel his fellow workmen by doing assigned work cheaper and better. In order that he may keep his timebooks and reports of material correctly, he should have a good common-school education. His habits should be strictly sober and his character moral so that he may with consistency enforce like virtues in his men. He should be looking forward to a higher position in the line of work in which he is engaged.

**Foreman of Fencing Gang.** The duties of the foreman of a gang engaged in the construction of fencing are not unlike those of the bridge gang foreman, and hence the two men should possess much the same general qualifications. However, the responsibilities resting upon the fence gang foreman are so much less than those borne by the other that a man who may be very successful at fence construction because of his vigor in pushing the work, might prove a total failure as bridge foreman. The fence work does not attract a very good class of labor, as a rule, and this fact increases the difficulties to be contended with by the man in charge.
Foreman of Painting Gang. The class of preparation and the executive abilities required to make a good foreman for a gang of painters for the maintenance of way department are analogous to those stated for the foreman of the bridge gang. The responsibilities are, of course, limited to the integrity and economy of the work executed by the gang, and the foreman in charge of this work lacks the stimulating influence which comes from seeking a higher position. It is particularly desirable that the foreman of painters should have the ability, based on actual experience, to estimate reliably the materials and labor required to do painting of various kinds.

Inspector. The inspector of bridges should be an honest and industrious man, who has a thorough knowledge of timber and its behavior under the variety of conditions prevalent in bridge work, and who is not afraid to assume necessary risks in making inspections of parts of bridges which are difficult of access. He should be able to cover territory rapidly and well, and should have enough schooling to enable him to express his observations on paper in a clear manner. The inspector should have been a successful bridge carpenter, and, provided he can manage men and work advantageously, should be regarded as eligible to the position of bridge foreman.

Bridge Watchman and Drawbridge Tender. The one essential quality of the bridge watchman and the drawbridge tender is constant
watchfulness. To perform the duties devolving upon this position in a proper manner, a man must be honest enough to perform his duty when he knows that he is not observed by his official superiors, and he should be capable of prompt and judicious action in cases of emergency.
By far the gravest responsibility connected with the operation of railroads is that resting upon the persons in direct charge of the repair and maintenance of railroad bridges. While a very full appreciation of this fact may be gained from a view from the rear end of the passenger train as it passes over a deep ravine on a timber trestle, or across the river spanned by a truss or girder bridge, the most vivid conception of the great load of responsibility resting upon the bridge department is to be had from a ride in the locomotive cab. The impressions resulting from an inspection trip of this kind invariably lead to a feeling of astonishment that serious bridge accidents are not more frequent than they are. In seeking the cause for this comparative immunity from a class of accidents seemingly so probable, much interest centers in the methods which are currently employed to preserve a proper standard of safety.

PILE AND TRESTLE BRIDGES. The prevailing type of bridge for small water ways in the United States is the trestle with pile or framed bents. The adaptability of this class of structure under existing conditions on most roads seems well established, so that the problem resolves itself into the selection of the most efficient and economical and standard plans to be used in renewing old bridges.

Standard Plans for Trestle Bridges. In discussing cross-ties, reference was made to the characteristic behavior of exposed timber
in the Southwest. The tendency to season only in a thin exterior shell and to rot in the heart of the stick should be given close consideration in the design of standard plans for trestle bridges. In view of this tendency, it is very desirable to expose as much surface as possible to the drying and seasoning influence of the atmosphere, and by this ventilation also to defer the process of decay. Thus in designing the stringer, if a 12 X 14-in. cross-section is sufficient to sustain the loads to be imposed upon the structure, the considerations of prompt seasoning and prolongation of life of the timber demand that two pieces 6 X 14 ins. each shall be used instead of the single stick. Since the adoption of the thinner timber serves to reduce the cost and also to improve the chances of getting a more uniformly good quality of timber, there is no excuse whatever for adhering to the former practice of using heavy and thick sticks of timber in the bridge stringer. The same observation refers to the sill, in which, owing to the proximity of the ground, the liability to early decay is much increased. In the case of posts in framed bents, the application of this principle is modified by the fact that the timber is exposed to the air on all sides, and that the almost universal dimension of 12 X 12 ins. is not seriously at fault in the matter of excess of cross-section.

No attempt will here be made to enter into theoretical requirements in the matter of dimensions of timber used in trestle bridges.
It is customary to use a liberal factor of safety, usually six or more, upon the assumption that there may be considerable fluctuation in the quality of the timber when new, and that renewals may be deferred until the strength of the timber is sensibly reduced by decay. A common dimension for the stringer of trestle bridges with 14-ft. spans on many Western roads is three pieces, 7 X 14 ins., separated by 4-in. cast-iron packing spools, thus making a total lateral width of 29 ins. The size of stringer used in 16-ft. spans, with somewhat heavier engines, is three pieces, 8 X 16 ins., packed in like manner, giving a width of 32 ins. With the 14-ft. span, it is common practice on the better roads to use 28-ft. sticks and break joints. With 16-ft. spans, however, the difficulty and expense of securing 8 X 16-in. timber in as great lengths as 32 ft. generally compels the use of single-length pieces. Where the latter practice is necessary, it is of the utmost importance that stop-blocks should be thoroughly secured to the caps to prevent lateral shifting of the stringer.

Pine timber is used exclusively for bridge work on many roads, although some which consume large quantities of pine, also use oak or cypress to a considerable extent. It is currently believed, and apparently with reason, that timber suffers deterioration with age and constant use. Recent tests by best authorities, however, seem to prove very conclusively that when timber is properly ventilated
and protected from undue exposure to the elements, the contrary of the prevailing opinion is more nearly true. Mr. Onward Bates, Engineer of Bridges of the Chicago, Milwaukee & St. Paul R.R., after a very full series of tests of full-sized stringers taken from actual service, has concluded that "green timber is not as strong as after it is seasoned," and that "age and use do not weaken the timber. It preserves its strength until weakened by decay". Tests of timber removed from a bridge after 31 years of continuous service on the Chicago & Northwestern R.R., made recently by Mr. W. H. Finley, Engineer of Bridges on that road, have confirmed in a conspicuous manner the deductions above quoted.

**Solid Floors for Trestle Bridges.** For the most part, the current practice in designing, building, and renewing trestle bridges in the West has been the gradual outgrowth of careful experiment and observation extending over a term of years. Very recently, however, there has been a decided innovation on several of the most progressive Southern and Southwestern railroads in the adoption of solid floors for the decks of trestle bridges, and extending the ballasted roadbed over the bridge unbroken. This has been the outgrowth of the similar practice introduced several years ago on the New York Central & Hudson River R. R. on plate girder bridges. The Southern Pacific R.R. and the Houston & Texas Central R.R. use the continuous roadbed only with trestles which are being renewed with
creosoted timber. The Illinois Central R.R. in its Southern lines used the continuous roadbed on solid decks of trestles located in low moist localities where ordinary grades of timber are short lived. Instead of creosoting the timber, the Illinois Central R.R. uses the black and red cypress, and estimates the life of the bridge at 12 years. Mr. J. F. Wallace, Chief Engineer of the last named road, states the main advantages of this design as follows:

"(1) Safety against fire.

"(2) Low expense of maintenance, as practically no repairs are necessary, all inequalities of line and surface being taken care of by the ordinary section force in the same manner as on any other section of track, thus doing away with the ordinary cost of bridge repairs.

"(3) These bridges give as good and easy riding a track as any portion of the solid roadbed, and the average passenger, not realizing that he is passing over a bridge, does not experience the feeling of insecurity frequently felt in passing over long trestles.

"(4) In case of derailment, there is less liability of damage to the bridge, and accidents due to this cause are therefore less serious in their nature."

There is reason to anticipate that this system of constructing decks will be widely adopted in the course of time on roads having a great amount of trestle bridging in swampy regions. The desira-
bility of using only the most durable timber, and of making the substructure as firm as possible is obvious, in view of the expense ultimately of renewing the deck. One very serious objection to the use of the continuous roadbed is in the absence of the guard tim­bers. In the absence of the side guards, the additional necessity of using good guards between the rails is very evident.

Piling. Various kinds of timber are used for piling in the construction and renewal of railroad trestles. It is usually neces­sary to give first consideration to the question of availability of the timber before making a selection between several varieties. Of the Southern oaks, the live, white, and post varieties are preferred for piles, because of their strength and fair durability. The swamp or red cedar which was formerly very plentiful in the South­west, makes an excellent timber for piling, owing to its unexcelled ability to resist decay. The red cypress has similar advantages, especially in swampy localities and is especially adapted to cases where great length and straightness are essential qualities. Pine is used to some extent, but owing to the tendency of the wood to bruise and crush in the process of driving, it is not a favorite. The short-leaf pine is much used for piling which are to be creosot­ed, and it is found that after the fiber of the log is filled with the preservative liquid, the wood is better able to resist the blows of the hammer. Other cheaper and more plentiful, but less durable
varieties of timber are often used for cases of small importance, but as a rule, it is poor economy to use such timber where it will have to be renewed. Where the work is submerged constantly, inferior grades of piling may, of course, be used owing to the well known fact that wood lasts indefinitely when saturated.

**Galveston Bay Bridge.** A notable instance of exceptional practice in the matter of pile renewals is found in the two pile bridges which cross Galveston Bay at Virginia Point, Texas. These bridges are parallel and belong to the Gulf, Colorado & Santa Fe R.R. and the International & Great Northern R.R., respectively. Their length is somewhat less than two miles and a quarter, and in the channel near the middle of each, is a wooden drawbridge of about 150 ft. span.

The most noticeable feature of these bridges is the frail type of their deck, the ties being only 2 ins. X. 8 ins. X 6 ft., and the guard rail being wholly absent. The reason for the meagreness of the deck is in the necessity for very frequently disturbing the ties for the purpose of driving piles, the ravages of the teredo, or seaworm, being excessively severe in the semi-tropical waters of the Gulf of Mexico. When the Santa Fe bridge was built about 1875-6, a large number of creosoted pine piles were driven, and where the preservative process was faithfully administered, the treated piling gave exceedingly satisfactory service, some of the best of them be-
ing still in service in 1892, apparently as sound as when driven, and entirely free from the attacks of the teredo. Unfortunately a majority of the creosoted piles in this bridge were prepared without adequate inspection at the works, so that a considerable portion of the soft pine that was used did not long resist either the tendency to decay or the inroads of the seqworm. The use of preserved piling in the Santa Fe bridge was the outgrowth of the excessive cost of pile renewals which had been developed by the construction of the parallel bridge some years before. In the course of a few years, the management of the Gulf, Colorado & Santa Fe R.R. adopted the plan of using a cheap grade of piling in Bay Bridge, upon the belief that the cheaper timber would last nearly as long as a more expensive kind. The elm was selected because it was found by trial to resist the attacks of the teredo about as well as other available woods which cost more, and on account of the fact that it prevailed in plentiful quantity in suitable size within a distance of fifty miles or so. The life of an elm pile having a diameter of 8 ins. at the small end is only about three years, although the same timber would not be disabled from decay for double that time. The care of this bridge requires the constant attention of a bridge gang and pile driver, and it is essential that an average of 100 piles per month be driven in order to keep the bents in desirable condition.

Estimates made from time to time indicate that the expense of
maintaining each of these bridges is about $10,000 per annum. Various plans have been proposed for putting them on a more economical basis, but as yet no satisfactory solution has been reached. It has been suggested that the two companies should unite in the construction of a joint bridge. But the combined present cost of operation ($20,000 per year) capitalized at 6% would amount to only $330,000 which sum is considerably too small to build and maintain a bridge of permanent character. Furthermore, it does not seem wise to consider the construction of a single track bridge having such an excessive length, particularly in view of the constant growth in the traffic of both lines. Since the ravages of the teredo are confined to a space of several inches at about the mean tide level, a plan for eliminating this costly element from the problem must embrace the protection of the timber at that point from the seaworm. Attempts have been made to enclose each pile in a vitrified pipe which is then filled with concrete so as to completely encircle the pile, but this plan was found to be very disastrous on a bridge over Lake Pontchartrain near New Orleans, La., where currents scoured the sand from beneath the enclosing pipe in shallow places, allowing the seaworm to attack and cut off the pile beneath. Since this danger was hidden from view, the first intimation of its existence was in the failure of several affected bents, and the precipitation of a train into the lake. Quite a little experimenting has been done in
covering the pile with sheet copper which is not affected by the chemical action of the salt water, but owing to the damage to the covering in driving the pile, and the difficulty of excluding the young worm, it is not probable that this method will ever be generally adopted.

The teredo attacks the wood fiber by means of a bony head, shaped something like an auger, and in time, the stick is completely honey-combed. Study of the habits of the animal early led to the knowledge that it could not bore with success into the palmetto, and this fact has led to the extensive use of that timber for construction of wharves in Southern waters. The palmetto is not a very strong timber, and for this reason has not been much used in the construction of railroad bridges. Besides, it is much bruised in the process of driving with a hammer pile driver, which fact has no doubt had much to do with the introduction of the jetting process of sinking piles in Southern harbors. Referring again to the question for a permanent plan for Galveston Bay bridge, it should be said that the excellent results secured with the few well-creosoted piles that were driven at the time of the first construction of the bridge, warrant the belief that the solution of the problem will be found in part, at least, in the use of creosoted piles. Another suggestion may be found in the admirable service rendered by a set of piers constructed from shell concrete at the draw span of the
same bridge. It is the belief of the writer that the final plan for these bridges will embody the use of concrete piers resting upon and enclosing piling treated by the creosote or other process, and that because of the rapid corrosion of wrought iron and steel by exposure in the neighborhood of salt water, it will be necessary to exclude metal work as far as possible. It may even be justifiable to return to the use of cast iron in some form owing to its immunity from the corrosive action.

Inspections. As often as once a year, the bridgemaster in person should make a detailed inspection of the trestle bridging of his division. For this purpose, it is excellent practice to use a light hand car propelled by four bridge men, one of whom may be the regular inspector. In addition to being of service in making the inspections and running the hand car, this small gang of men serves a valuable purpose in making such emergency repair as may be found necessary in some cases. The inspections themselves require the use of a 3/4-in. steel bar with one end made diamond-pointed and the other shaped like a ball. Besides this tool, a long augur of small size and a ratchet brace and small bit should be a part of the equipment. In testing the timbers of the trestle, the ball end of the bar is used to sound the pieces and the pointed end serves as a prod to determine the depth to which apparent defects reach. In timbers which seem to have defects at the heart, the augur or, in cramped
places, the ratchet brace and bit, should be used to bore a hole to the desired depth, and after the inspection of the point is completed, the hole should be thoroughly plugged to exclude the water. A careful record should be made of the examination of each bridge, and a system of branding or marking the timbers should be adopted, in order that the foreman may subsequently act with intelligence in making repairs to the bridge. After this annual inspection of the bridges is completed, a program for repairs and renewals is prepared by the bridgemaster who immediately makes a requisition for the timber required for the execution of the work. It is very desirable for the division engineer to accompany the bridgemaster in his entire trip, if the time can be spared from other matters for the purpose.

In addition to the special inspection by the bridgemaster in person, the inspector of bridges, of which there should be at least one to each 500-mile division, will keep constantly on the road in the continuous examination of the bridges. His inspections are for the purpose of detecting imperfections which develop between the annual inspections, and can not be safely deferred. The method of making the inspections are essentially the same as those used on the annual trip, except that the inspector uses a velocipede car, and conducts the inspection usually without assistance. On some roads the inspector reports directly to the engineer of maintenance.
of way, so as to have entirely independent reports as to the condition of the bridging. This plan is found to have a salutary effect upon those responsible for the safety of the structures, and it is found particularly valuable in case of a dispute as to the real condition of a structure which may sustain an accident. It is often desirable when a lot of requisitions reach the hands of the engineer of maintenance of way that he should confirm the judgment of the bridgemaster as to the condition of the timber in the bridges which are to be renewed, and for this purpose the inspector is indispensable. As a matter of justice to the bridgemaster, however, the engineer of maintenance of way should have before him a copy of the general program of the order of renewals and repairs as formulated after the annual inspection, for otherwise he will be apt to cut out some material that seems useless. Some bridgemasters are disposed to work ahead in an aimless manner, and this plan of requiring a definite program to be made and a copy of it sent to the head of the department through the hands of the division engineer, serves to spur such a man to become a more useful servant.

System of Bridge Renewals and Repairs. No other single feature of the work of the bridgemaster so thoroughly tests his ability as the preparation of a program. By having a clear conception of the necessities of his division, he can plan to renew, according to standard plans, certain of the most defective bridges, and by using
the better of the old material taken out to repair other less urgent bridges, he can effect a marked saving in the maintenance of the structures assigned to his care. If an account be kept of the cost and repairs of each bridge through a term of years, giving credit to the structure for the value of the material taken out and used elsewhere, it is very certain that the cost of actual repairs will be found to be very small. The old stringers and other timbers which are not suitable for service in other bridges, serve a most valuable purpose in the construction of retaining walls and bulkheads and a systematic account should be kept so that none of the material will be wasted.

METAL BRIDGES. If plate girder and truss spans are properly inspected during their construction, there is little occasion for close inspections until after the structures have been in use several years. The first coating of paint, if of good quality and well applied, will usually last for 4 or 5 years. Before the painting is renewed, a gang of bridge men, under the direction of a competent foreman, borrowed preferably from a reputable bridge construction company, should be sent over the line for the purpose of overhauling in a thorough manner the riveting and other details of the bridge which may be susceptible of serious deterioration. This gang should be supplied with a complete kit of tools and implements required for the prompt execution of such work, the outfit being contained in a
box car, or a rejected caboose. As a rule, it will pay to employ a competent bridge engineer to make an inspection of the metal structures which require the repairs, in order that the necessary material may be provided for the use of the gang, and so that especially urgent cases may be given preference. Systematic methods should be employed in the prosecution of these repairs, a complete record of the condition of the bridges and the extent and nature of the repairs made, being kept by the man in charge of the work. This record is carefully copied and the original preserved for future reference in the office of the engineer of maintenance of way.

Painting Metal Bridges. Immediately following the repair gang just mentioned, should come the gang of painters. The painting outfit should be contained in a car set aside and equipped especially for the needs of such work. The kit of implements should include extension ladders, stagings with blocks and falls, an ample stock of brush tools and scrapers, and a sufficient surplus stock of white lead, oils and other essential painting supplies. A small stock of the standard paints should be allowed in the surplus supply to piece out deficient invoices of material. This provision may often save several times over the value of the stock so carried, by avoiding useless waste of time and annoying delays in waiting for the deficient materials to be supplied on special order.

In painting metal work, the importance of removing the old
scale completely before applying the new coat of paint can not be 
too forcibly emphasized. That this precaution is commonly slighted 
is shown by the poor service rendered by the repainting of many 
bridges on which the best of material was used.

The process of inspections and repairs before repainting as 
above outlined is not systematically carried out on very many roads, 
probably for the reason that too many railroad managers are inclined 
to look upon the iron or steel bridge as everlasting. An especially 
favorable feature to the employment of a competent bridge engineer 
to make in person the inspections preceding the repairs, is that he 
may at the same time investigate and make a record of the develop-
ment in the weights of the locomotives and cars used on the road, 
so that the bridges may be re-inforced, or replaced by heavier 
structures, when the loads become too great. In this connection, 
it seems pertinent to commend the admirable foresight which has led 
to the adoption on some roads of two or three standard lengths of 
span. By this system, the first cost of bridges is sensibly reduced, 
since the bridge companies can execute the work more cheaply in the 
shop, and an opportunity is afforded to shift bridges from main line 
to branch when increased loads or amount of traffic requires the 
removal of a main line bridge.
BUILDINGS. Little attention was given formerly to the question of esthetics in the design of railroad buildings, but in more recent years there has been a growing tendency to appreciate and utilize this very effective means of beautifying the line of the railroad. The Pennsylvania R.R. was the pioneer in the study of this important matter, and its standards have served as a basis for the plans subsequently adopted on numerous other first-class lines. The development of the esthetics of railroad structures has been so marked as to justify the recent publication of an elaborate treatise on railway structures, in which much attention is devoted to this phase of the subject. While the older and wealthier lines of the East are able to carry this matter to an extreme point in landscape gardening and even to the details of the track standards, the average Western road may be considered fortunate if its architecture fulfills the simple requirements of cheapness and convenience. On many roads in the West, no small degree of progress has been made toward the higher standard, but in still more cases there is evidence of a flagrant disregard of the first principles of good taste in the design of buildings, and in many instances, little evidence can be found that any considerable thought was given to the adaptability of the building to the intended use, or to the element of economy in construction or repairs.

Before adopting standards of design for the several types of buildings needed in railroad service, it is wise to secure copies of the standard plans used on other roads having like controlling conditions, and also to make special inspections of buildings on neighboring roads with the view to avoid bad details, as well as to get suggestions of good ones. In weighing the various phases of the subject, the engineer of maintenance of way should have sufficient taste and foresight to cause him to adopt that class of design which will most effectually combine reasonable first cost, convenience for the proposed use, and consistency and beauty in architectural effect.

In making the selection, it is important that the character of the country as regards landscape be given due consideration, since a design that is suited to broken and mountainous country may not suit prairie country. In the matter of ornamental detail, it is important to discriminate, on the one hand, against offensive profusion, and, on the other, against excessive plainness. In the same connection, attention should be given to the choice of tasteful and durable standard colors for painting buildings. This point is so important as to afford an opportunity to outweigh and conceal, in no small degree, very gross errors in the design of buildings, and likewise, a first-class design may be spoiled in appearance by the selection of ill-adapted colors for painting. While the color
should be such as to weather well, and not tarnish seriously with exposure to smoke, the very common error of selecting very sombre tints should be avoided. In order to secure uniformity in the paint from year to year, a standard number or set of numbers, as designat-ed in the samples of a first-class manufacturer of paints, should be selected and strictly adhered to. It is quite common to overlook the importance of affording plenty of ventilation, and this subject is related to that of light. In Northern latitudes, the severity of winter weather may demand a comparatively small glass exposure, but in the South, comfort in the use of the building depends very large-ly upon the liberal size of the windows. In adopting windows of ample size the question of economy in glass repairs suggests the use of comparatively small sized panes.

No attempt will here be made to present a set of designs for railroad buildings, as the subject is much broader than may be done justice in the space and time available. It is sufficient here to state that the principles of consistency and economy involved in the design, construction, and maintenance of buildings, are essen-tially the same as those which should prevail in all other branches of the maintenance of way department.
OFFICERS. Foreman of Water Service. In addition to having at least a common school education, the foreman of water service should have filled for a sufficient term of years such subordinate positions in the water service department as will have made him thoroughly conversant with all details of the work of that department.

It has been asserted that the foreman of water service should be the "jack of all trades, and the master of them as well." Such is, perhaps, more nearly true of him than of any other servant of the department, for the necessities of his work may require him to display no small degree of skill as a pipe-fitter, machinist, and steam-engineer; he is, besides, not infrequently called upon to participate in, and perhaps direct, carpentry work of a more or less difficult character, and the problems in well sinking for which he must at times assume the entire responsibility, often involve difficulties and dangers which are second only to those encountered in sinking deep mine shafts. It is, furthermore, sometimes necessary for him to take charge of the construction of reservoirs, requiring a practical knowledge of handy earthwork, often under adverse and very unusual conditions, and also demanding a knowledge of the use of explosives for the removal of stumps and boulders. He is also called upon to direct or supervise masonry work of considerable impor-
tance, and it is frequently necessary for him personally to partici-
pate in the construction of pump and boiler foundations which are
of such small size as scarcely to warrant the expense of sending a
mason to the place.

Aside from the skill and knowledge thus demanded in so many
fields of work, the foreman of water supply must be a man of keen
judgment and foresight, particularly if the division upon which he
is employed, traverses a dry country. Since the great majority of
his men work individually instead of in gangs, as in the other de-
partments of maintenance service, they lack the salutary influence
resulting from association with other men employed in the same class
of work. For this reason, the head of the water supply department
is required to exercise the closest scrutiny in selecting his men,
and to discriminate wisely in the assignment of stations of special
importance. On account of the isolation of the pumpers, it is nec-
essary to adopt and enforce a kind of discipline which is quite dif-
ferent in essential points from that used in other departments.
Considering carefully these various duties of an onerous character,
it does not seem surprising that first-class foremen of water ser-
vice are exceedingly scarce.

Assistant Foreman of Water Service. The assistant foreman of
water service should be a man who is industriously acquiring the
preliminary training needed to fill with success the higher position
just described. He should have a sufficient degree of aptness in the various kinds of work that may arise, and should invariably work on the principle that "what is worth doing at all, is worth doing well". While he may fairly have the ambition to attain the higher position, he must be intensely loyal to his superior at all times, and co-operate with him by assisting as far as practicable in the execution of disciplinary matters.

Pump Repairer and Helper. The pump repairer should be a good bench workman so that he may execute repairs well in the shop, and besides should have the ability to make temporary repairs on pumps and boilers without removing them to the shop. He should be a man who can be relied upon to make the most of the facilities available, particularly when sent on his own responsibility to make repairs in cases of emergency. The pump repairer should be constantly on the alert to show his worthiness to fill the higher position of assistant foreman of water supply.

The helper is preferably a man who is able to do the work of the repairer when necessary, and who is industriously striving for the better position.

Pumper. The pumper must have a sufficient knowledge of the principles governing the steam pump and boiler to enable him to operate such a plant economically and safely. He should have the skill needed to make minor repairs, so as to save the time of the
repairers for more urgent work, and should study the plant with a view to learn what it may accomplish without undue wear and tear. He should conscientiously watch his tank and see that it is kept full enough all the time to prevent leakage at the top from shrinkage of the staves. Since his actions are not subject to constant inspection, he should appreciate the special responsibility thus imposed upon him, and in protecting the property entrusted to his care, should be actuated by a feeling of genuine loyalty to the company for which he is working.
SOURCES OF WATER SUPPLY. The usual sources of railroad water supply are as follows: (1) wells; (2) reservoirs; (3) streams or rivers; (4) local water-works. Consideration will be given to each of these sources of supply.

WELLS. Curbed Wells. By far the most common method of securing a supply of water for the operation of railroads is from wells. The selection of well sites for this purpose involves essentially the same points as for domestic or other ordinary needs, except that consideration must be given to the much greater quantity of water required. The latter fact is often called to mind in prospecting for water in a new country, it being necessary to receive with caution information given by local parties in relation to the quantity of water to be had from wells in a given locality. This is particularly true of the exceedingly drouthy regions of the West and Southwest, where it is common to hear wells spoken of as never having been known to go dry, and in many such cases the supply would be exhausted in a very short time if used to supply locomotive service.

As a rule, wells yielding a large supply are located in sandy or gravelly soil contiguous to a stream of water. A common type of surface well is made under these conditions by sinking a wooden or masonry curbing to a sufficient depth and excavating the material
from the inside. This plan gives entire satisfaction under most circumstances, but in case the stratum resembles quick sand in its nature, it is found that the inflow of water causes the well to fill with sand, making it necessary to clean the well out periodically. The length of time between successive removals of the material thus deposited, depends altogether upon the character of the sand and the rate of consumption of the water. The methods used in starting and sinking the curbs are essentially the same as those employed in shaft sinking. When the curb is made entirely of wood, it is important to select cypress or other timber having marked durability in damp places, and if the well is to have considerable depth, the vertical planks ought to be arranged to break joints so as to avoid weak points at which the curbing may fail prematurely after the process of decay sets in. If brick curbing is used, it is customary to construct a strong and well bonded wooden footing with a cutting edge made of boiler plate. Much care must be exercised to remove material symmetrically in order to keep the masonry in a vertical position. As the depth increases, and the weight of the masonry becomes excessive, the danger from pockets of quicksand or other soft material is much greater. At this critical juncture in the work, every effort must be made to push the work to a rapid completion, since a stratum which may have the firmness to resist the pressure exerted by the masonry curb for a day or two, may sud-
denly give way with disastrous results, both to the work and to the men employed in its execution.

A quite interesting example of such experience with a brick curbed well occurred some years ago at Sealy, Texas, an important division point of the Gulf, Colorado & Santa Fe R.R., about 100 miles from Galveston. Shallow surface wells had proven totally inadequate to the heavy demands upon the water supply and it was decided to attempt a deep curbed well. A prospecting pipe sunk at a point selected for its convenience as a site for the pumping plant, showed a red and yellow sandy clay for a depth of 50 ft. or so, after which a stratum of water-bearing sand was reached having a depth of about 20 ft. It was decided to sink a brick curbing to this sand stratum, and the inside diameter of the masonry was fixed at 20 ft. The wooden toe with cutting edge was started and the masonry was kept about even with the surface of the ground so as to economize handling the materials. No special difficulty was experienced until the footing reached the sand, when the brick cylinder showed signs of unequal settlement. Decisive action was necessary since the condition grew worse and worse for several days, the wet sand running in more from one side than the other, causing cracks to form in the masonry near the foot, and forcing the shaft out of its plumb position as far as that was possible with the guiding tendency of the 50 ft. or so of firm clay. Attempts were made to get a re-estab-
lishment of the equilibrium by removing additional sand from the side having the more sluggish flow, but this did not seem to succeed. An effort was then made to check the inflow by driving sheet piling, but it was impossible to get the piling close enough together to stop the flow, although a marked diminution was effected. Various materials were tried as a means of plugging up the crevices, but with comparatively little success until a test was made of stable manure which accomplished the desired end in an astonishingly satisfactory manner. This material was rammed into place behind and around the sheet piling and the flow was stopped by the increased bulk upon becoming wet. The wall settled back into form and as promptly as possible the masonry was completed. After this, the sheet piling was removed very cautiously and the curbing was found to stand without sign of weakness. As the work was in progress, T-rails were built into the brick work to serve as support for a winding staircase and to hold the pump platform which was put in place within suction lift distance of the water level.

In the case just described, the curbing itself was, of course, practically impervious to the passage of water, the supply of water passing in from below. It is sometimes essential that the curbing shall reach and rest upon bedrock, in which event, it is essential that the curb shall allow the free passage of water. A wooden curb with open joints will do this in a fairly satisfactorily manner, but
it lacks permanency. The most satisfactory well curbing for this purpose is constructed from coarse, flat stones, laid up in the form of a well bonded dry-wall. If desired or considered necessary, a few feet at the top of the wall may be laid in cement or lime mortar to make it safe against disturbance.

**Driven Wells.** In sandy strata bearing an abundance of water, a good supply can usually be developed by driving a series of tubes or pipes with strainers at the lower end. If the sand is exceedingly fine it may give trouble by clogging the strainer. The Cook Pump Co., of St. Louis, Mo., manufactures a strainer which is practically free from this danger, owing to the V-shaped cross-section to which the aperture is formed.

In sinking the pipes, a driver may be used with good results, but in sandy soil it is much cheaper and quicker to use the jetting process. The latter may be done by using a small portable pumping outfit, and such small supply of water as may usually be had in such a locality. In case the strainer becomes clogged, it is a simple matter to insert a small hose or piece of pipe and scour out the accumulated sand. It is a good plan to connect driven wells up into gangs as it is usually found that the pump works more economically than with isolated pipes.

**Artesian Wells.** Comparatively few artesian wells afford water of a quality that serves satisfactorily in locomotive boilers. One
reason for this is no doubt to be found in the fact that waters from several tanks are often mixed in the locomotive tender, and by this means chemical constituents which are harmless or comparatively so when acting alone, are brought together with detrimental results. At any rate, numerous instances are known of artesian water being used for stationary boilers which gave poor satisfaction under the more severe requirements of locomotive boilers. Owing to the great scarcity of water in many places on the Western plains, it has been necessary to use artesian water indiscriminately, and often with serious damage to the locomotive boiler. In fact, poor boiler water is so common in some parts of the West, particularly where the artesian supplies have to be relied upon, that special instruction is necessary before the locomotive engineer can be safely entrusted with the care of a locomotive.

Quite extensive artesian supplies have recently been developed near the Gulf coast. The writer had charge of the pioneer artesian well sunk on Galveston Island in 1886-7 by the Gulf, Colorado & Santa Fe R.R. The depth of this well was about 800 ft. It was sunk by the revolving-jetting process patented and operated by the American Well Works of Aurora, Ill. A supply of about 100,000 gallons per 24 hours was secured from this well, but owing to its containing an excessive quantity of alkaline elements, no use could be made of it even for stationary boilers. Notwithstanding the brackishness
of this water, the city of Galveston subsequently spent a large sum of money in sinking wells to the same strata. The result of the heavy draft upon the supply soon became evident in the diminished flow of the older wells, and the city of Galveston has since established an artesian system on the main land at a distance of some 14 miles.

Occasionally, artesian wells flow to a height sufficient to fill a railroad tank, and when such is the case, the supply costs practically nothing to maintain it. When the head of the well is not sufficient to lift the water into the tank, an hydraulic ram may be used to lift a portion of the water provided arrangements are made to secure a gravity impulse with a little storage to operate the ram. One obstacle to the use of the hydraulic ram for this purpose is in the excess of sand which often prevails in artesian wells, the effect of the sand upon the valves of the ram being very noticeable.

RESERVOIRS. In countries where good wells are not to be had, the construction of reservoirs is a necessity, and very often the reservoir supply proves to be cheaper and better when a well supply is also to be had. The selection of a reservoir site is a matter of no small moment, it being necessary to collect and consider full data in relation to the location of the site as regards convenience of traffic, character of under-lying strata as regards their water-
tightness, availability of suitable stone to construct a dam, mini-
mum rate of rainfall and its distribution throughout the year, preva-
ience of storms which might endanger the dam, etc. Still another mat-
ter that should be given consideration and test before deciding upon the reservoir plan of securing a water supply, is that of the quality of the water at low stages of the reservoir. In the experience of the writer in the dry regions of the Southwest, this is a matter giving no small amount of trouble, owing to the concentration of the alkaline waters due to excessive evaporation in long drouths.

Before finally selecting a site for reservoir purposes, a special survey should be made of it, including contours, so that a reliable estimate of the storage capacity may be made. In examining the water-shed close attention should be given to the tendency of the soil to scour and to deposit in the form of mud or silt, and allowance should be made for the reduction in the storage capacity due to the silting up of the storage basin. In designing the dam, provision should be made for cleaning the silt out in times of ex-
cessive rainfall, and for this purpose, a gate may be put in a ma-
sonry or wooden dam at a point low enough to take the deposit out. For this purpose, a rapid and also cheap plan is to set up a special pump and hydraulic the mud out by means of a large hose and nozzle. In the case of earthen dams, it is exceedingly unsafe to attempt to
maintain gates of the kind just referred to owing to the tendency of the water to find its way along and around the walls of the gate. With such dams, about the only way to clean the silt out is to await the opportunity afforded by an extended drought, when the low stage of the water admits of the use of teams and scrapers.

In considering the maximum rate of rainfall that will fall upon the water-shed and the quantity of water that will be likely to pass the site of the dam at such times, it is of the highest moment that due provision be made for the waste of the surplus water without danger to the structure. With the masonry dam of the dimension generally used for railroad reservoirs, it is customary to utilize the entire length of the crest as a waste way. This is wise as a rule, inasmuch as the best grade of masonry work is usually done upon the main body of the dam, although it is very important that the wing walls of the dam should not be slighted in the least. With the earthen dam, it is absolutely essential that no water shall pour over the earthen crest and provision should be made for liberal wastage through one or two well-built timber flues which should be water-tight or nearly so, and should have an outfall well away from the toe of the slopes of the dam. A very important detail of the waste way is the construction of the apron at the head, inasmuch as there is great liability to develop leakage at this point. A first-class apron may be made by the use of concrete enclosed by cypress
or other durable lumber.

A very good dam may be constructed from logs built up in log-house fashion, and filled with boulders, clay, gravel, etc. A good wasteway may be made over the top by making a substantial apron of lumber, which should be laid in pitch or other water-proofing material. The log dam may safely be provided with the gate already referred to if due care is taken in designing the details.

SUPPLY FROM STREAMS OR RIVERS. With ordinary streams or brooks no especial difficulty is experienced in establishing and maintaining a water supply, provided the quantity and quality fill requirements. The pumping plant may be located near a natural hole in the bed of the stream, or if necessary, a small dam may be constructed to impound the supply required to cover the suction pipe, or at a low stage of the stream, a sufficient hole may be excavated by means of scrapers.

In the case of good-sized streams and rivers, having high and steep banks, and especially when subject to excessive fluctuations of water level, it is often a matter of no little difficulty to establish a plant that will run satisfactorily under all conditions. One way of providing for the fluctuations of water level is to keep two pumps in place, one for low stages, the other for high. This is somewhat expensive, however, especially since it is difficult to provide a house or covering for the low-water pump, which will not
be damaged to a considerable extent by being submerged, if, indeed, it escapes injury from passing drift.

A plan that is sometimes used for a case like this is to provide a means for raising and lowering the pump to suit the stage of the water. The pump platform may be arranged to work in guides on an incline, and the movements may be regulated by means of a screw, or a block and falls. Some annoyance is found in the use of this plan by the changes in the connections of the steam and water pipes, and as the distance from the boiler to the pump increases, and it would obviously be of considerable length a majority of the time since high stages are usually comparatively brief, the loss due to radiation and condensation would be considerable.

After giving close consideration to this problem, the writer has concluded that the most economical plant in the long run is the deep-well pump, the pumping plant being located near enough to the bank of the river to admit of the pump being set low enough in a vertical line to reach the lowest stage of the water, and that without requiring an excessive length of suction pipe. This judgment has been conclusively proven to be correct through a careful comparison of the two methods at the same site.

SUPPLY FROM LOCAL WATERWORKS. In cities or towns of good size, it is often the cheapest and best plan to purchase water from the local water-works and this is especially apt to be the case in
large cities, or where the railroad demands a large quantity of water and the cost of establishing and operating a special plant is excessive. As a rule, the railroad company can afford to pay somewhat more for the water than it might hope to supply it for by a plant owned by itself, for the reason that the supply of the waterworks would probably be more reliable.

Water purchased from a local water-works may be delivered to the locomotive by direct pressure from the mains, through the medium of a water column, or the water may first be delivered into a tank and thence into the tender of the locomotive, either through the ordinary spout or by means of a water column.

IMPROVEMENT OF EXISTING SUPPLIES. One of the most important duties requiring the attention of those engaged in the water service department is the development of existing water supplies. Various means of supplementing short supplies are developed in the exigencies of this class of service on roads traversing regions of a more or less arid or drouthy character.

In wells sunk into sand strata, a favorite method of obtaining greater quantities of water is to sink strainers into the bottom of the well by means of the jetting process and then putting branched suction pipes into these strainers. This plan is especially good when a well needs cleaning out, and owing to financial or other reasons, the work can not be immediately undertaken.
Where the well is in clay soil and the curbing rests upon the bedrock, an exceedingly effective device for improving the productive quality of the well is to drive tunnels or galleries in radial lines from the main well. These galleries should be along bedrock and they should be made about 4 ft. high and wide enough for a man to work with some convenience, say 2 ft. wide. The bottom or floor of the gallery should be cut into the bedrock a little so as to act as a drain toward the main well, and the bottom of the well should be blasted out so as to form a suction basin at low stages of the well. It is obvious that each lineal foot of the gallery has the same collecting power as two lineal feet of the circumference of the well. The writer has used this plan on a somewhat elaborate basis in the improvement of a large well at Temple, Texas, and the results of this test of the method were of an exceedingly satisfactory character. A somewhat similar plan is found to be effective where a reservoir is seemingly about dry ditches dug in various directions into the silt having the effect to concentrate the water to a point where it can be reached by the suction pipe. By this means, a supply that is apparently exhausted may often be made to span over a critical period, and prevent the use of water cars.
WATER SERVICE PLANT. The plant of the railroad water supply system includes the following parts: (1) the pumping plant, consisting of steam boiler and pump, or their equivalent in wind mill and pump, or in water purchased from a local water company; (2) the delivery plant, consisting of the system of water mains and pipes, and the storage tank, or the water column.

PUMPING PLANT. Steam Boilers. Steam boilers for railroad pumping plants should be made in the best manner from soft open hearth steel of first quality. The details of the shell, fire box, flues, etc., should be well designed, and the various parts should be susceptible of ready access and repair. While the plates should be amply thick to withstand the pressures to which the shell will be subjected, the boiler should be made as light as is consistent with safety in order that it may not be unnecessarily cumbersome for the small forces that are available to handle it. Boilers of several standard sizes should be used to accord with the varying requirements at different stations. In order that there may not be a needless delay in case a boiler gives out suddenly, several boilers should be kept in reserve at convenient points.

Pumps. It is deemed wise to adopt one standard make of pump for use at all stations on the division or the entire road. The principal advantage in this plan is in the simplifying effect which it has upon the matter of repairs. It is, of course, somewhat dif-
difficult to choose a make of pumps that is certainly the best to be had, but it may be said that there are several well known manufacturers of small pumps, whose product has been proven to be well adapted to the needs of railway water service. Among these are the Dean and Knowles pumps which the writer has found to give most excellent results under a wide variety of conditions.

In selecting a pump, due consideration should be given to the elements of economy of operation, simplicity of design, durability of construction, and cheapness. After the selection is made, one or more reserve pumps of the different sizes should be kept in stock so as to keep in progress a systematic and comprehensive plan of repairs. The only efficient means of keeping railroad pumping machinery in proper condition, is to exchange the pump that is in proper order for the one that needs overhauling, and then to execute the repairs in the shop where liberal facilities and a stock of duplicate parts are provided. The writer has made a comparison of this systematic plan conducted under the direction of a water service foreman of exceptional ability, with a hap-hazard plan followed on a neighboring division, and it should be said that in the course of two or three years, the results were strikingly in proof of the wisdom of the former plan.

Windmills. The extent to which strong and constant winds prevail on the Western plains, has made the use of the windmill as a
means of pumping water quite popular. Its application to railroad water service has been found to be very economical in many instances although for important stations, it is usually necessary to operate a steam pumping plant in addition to the wind pump. In some localities, the prevailing winds are rather too light to warrant the use of large wheels, owing to the large proportion of the time that the wheel is motionless. Under these conditions, it is much wiser to use several smaller mills which are geared back so as to be affected by the slightest breeze.

DELIVERY AND STORAGE PLANT. Pipe Systems. The design of proper systems of mains and pipes for railroad water service often requires no small degree of skill. Due care should be taken to make the lines as direct as possible, and ample and thorough provision should be made for draining the system so as to avoid damage in freezing weather. A careful record with dimension sketch should be made of all pipes and connections at each station on the division, and as new data are secured, they should be preserved with the official record. In designing pipe lines, the loss of head in the pipes should receive due consideration. In this connection, it is necessary to know approximately the quantity of water which will pass through the pipes, and to this end a careful record should be kept in the office of the foreman of water service, showing the consumption of water at each station. This record should be based
upon careful monthly estimates made by the pumpers, the number of locomotives taking water being the basis of the estimate. Such a record makes it practicable to classify the water stations according to their importance, and this classification will serve as a quite definite and satisfactory foundation for estimates required in the establishment of new stations. A printed blank should be used in making the monthly statements, and the water report should be transmitted through the office of the division engineer, to the head of the maintenance of way service.

**Water Tanks.** The storage tank is usually made with wooden staves and bottom, supported on a framed wooden support. The bottom and staves are best made from the red cypress, although red cedar and white pine are preferred by some. The life of a good cypress tank is upwards of twenty years, as a rule, although it may last longer if well cared for, or may have a shorter life with neglectful treatment. A common dimension for railroad tanks on many Western roads is 16 X 24 ft., although some lines have several standard sizes adapted to varying requirements.

The details of the cross-arm and counterbalance weights, and of the gooseneck and spout connections should be of a simple character, so that derangement will be improbable, and in order that temporary repairs may be made by trainmen, if need be. The roof should be of a simple character with a tasteful finial and ornament. The foundation is best arranged on the isolated pier plan, though many
roads use the wall sill plan. With the pier plan, the capstones should be slightly pyramidal on the top and the lower ends of the posts of the frame should be slightly hollowed out to suit, in order to secure drainage and prevent rot of the timber where it comes in contact with the stone. The framework should be simple in detail and due consideration should be given to the stability of the structure after the process of decay has set in.

The tank should be thoroughly painted as soon as the first leakage has been stopped, and the coat of paint should be renewed about every fourth year. It is of much importance that the hoops be adjusted properly, for if left too tight, there is imminent danger that they will burst, causing the failure of the entire structure; and if left too loose, the constant leakage will be a source of much annoyance to those using the tank, and of damage to the timber in the staves and bottom.

At important division points, it is often necessary to erect elevated tanks for the purpose of supplying sufficient pressure for washing out locomotives and securing fire protection. The height of such tanks is usually from 40 to 60 ft., depending upon the necessities of the case. The framework is usually made of timber, although some roads have recently adopted the more permanent plan of using steel towers. A very recent design on a Western road consisted of a steel tower supporting three wooden tanks at different elevations, so that different pressures could be secured for the vary-
ing needs of a division point. This case is suggestive of the line along which there is much room for development in the future. At first thought, it would seem very desirable to adopt metal tanks set on first-class masonry foundations, such as are in use on some roads in the West, but experience with such presumably permanent structures has failed to show them altogether satisfactory, owing to the tendency of the tank to corrode. However, it would seem that this difficulty might be eliminated by the use of best methods and materials in the first construction and in the subsequent maintenance, in which the painting is a very important item.

Water Columns. The use of the water column has become quite common on all first-class roads. Objection is sometimes made to the use of the water column when connected directly with the pressure mains, owing to the hammer resulting from the more or less sudden stoppage of the water when the valve is closed. With the earlier forms of the water column, the objection seems to have been a just one, but the manufacturers of this device have improved it by increasing the capacity of the relief valve, and it is now claimed that the water column may be connected with mains bearing very high pressures without producing a noticeable effect when the valve is closed.

The water columns which are used most generally on railroads in the United States are the following: Poage's Automatic Water Column, Dodge Water Column, Mansfield Railroad Water Column, and
Sheffield Water Column. The following essential requirements of a good water column are fairly complied with by each of those above named:

"1. A large area of passage from entrance to exit of water, with a quick operating valve, and with the least possible friction in the pipes.

"2. An efficient safety valve to prevent concussion by the sudden stoppage of a large body of water.

"3. It should be adapted to high or low pressure and should be frost proof.

"4. It should turn automatically to a position parallel with the track and should be suitable for single or double tracks.

"5. Valves should be well balanced for ease of working, valve and all its parts easily accessible and capable of quick removal and replacement of duplicates.

"6. A slight disturbance of the vertical alinement should not disturb ease of rotation.

"7. It should have a perfect automatic appliance for quick drainage of pipes after use."

One of the commonest errors in establishing water cranes is in the use of mains of too small size, resulting in useless waste of time in watering locomotives. It is not uncommon to see the absurd combination of a 4-in. water main and an 8-in. water column.

Another blunder in setting columns is in placing them too close to the track. This defect is not so apt to occur in the North as in the South, the chief danger in the latter locality being in the transportation of compressed cotton exposed on flat cars. The cotton jars loose and projects far enough to demolish a crane which would ordinarily clear cars with safety. Owing to this fact, it is unwise to place the water column closer than 8 ft. from the center of the track on Southern roads, so that when placed between two
tracks, they should be on 16-ft. centers.

REPAIRS TO PLANT. The successful administration of the water service department is very largely dependent upon the provision of a well-equipped repair shop. The equipment should include the usual bench tools, a good forge, a lathe of small size, and a limited amount of power. The stock of duplicate parts of pumps and of water columns and other plant of the department should be complete enough to prevent any serious delay in restoring a damaged or defective part of the system. A set of patterns for making spouts should be made and the spouts themselves should be made from the proper grade of galvanized iron kept in stock for this purpose. A surplus stock of blank hoop material should be at hand and at slack times the holes should be punched for attaching the bolt lugs. A full kit of scrapers, plows, etc., for building and cleaning out reservoirs should be provided for the water supply department, in order that they may be entirely independent of the plant belonging to other departments. There is also a positive necessity for a good derrick with a liberal supply of blocks and ropes of different sizes, and for several good screw and hydraulic jacks. A complete invoice of the equipment should be kept and the division engineer should go over the stock in person from time to time in order that he may intelligently act in making requisitions. One of the most profitable investments for the water service department is a complete outfit of pipe and thread cutting tools of latest design by the best maker.
CONCLUSION. Only the more important features of railway water service have been discussed. The subject is an exceedingly broad one, inviting closer consideration than could be given to it in these pages. The comparative obscurity of many points of the work of this department of maintenance of way often leads railway officials to consider it of minor importance. This error is liable to add greatly to the expense of supplying the road with water. Instead of pursuing a narrow and parsimonious policy, there is substantial reason to believe that in no other single line of service will liberal expenditure, judiciously made, yield more prompt and material returns.
APPENDIX I.

THE READJUSTMENT OF

LONG RAILROAD TANGENTS.

From The Technograph No. 8.
1893-4.

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THE READING OF LONG RAILROAD TANGENTS.

By Wm. D. Pence, Assistant Professor of Civil Engineering.

It is a well-known fact that few railroad tangents of extraordinary length, and, as a rule, of moderate length as well, are in reality right lines; or, to state it more precisely, their horizontal projections are not right lines. The various causes leading to deviations from the true tangent are more or less familiar to all engineers, and it will suffice to refer to the more important of them without attempting an extended discussion. In general the deflections in a railroad tangent are traceable to one or more of the following elements: (1) errors in the manipulation of the transit in the original survey, the most frequent and also the most serious instance of which occurs when in prolonging the line by reversal, the transitman fails to take double sightings; (2) discrepancies in the original track centers owing to instrumental errors or those resulting from the use of disturbed reference points, or perhaps, to the fudging required to make the
track bisect a bridge or an embankment constructed to one side of the true line; (3) failure to lay track to true centers; and (4) shift in center line by repairs. To this list may be added "atmospheric condition" as regards its influence upon the accuracy of the survey. Although the last named element is of little or no importance in cool or cloudy weather, there is no doubt that sensible errors may and do result from attempts to take long sights under the extreme influence of the solar heat. Since this condition is usually more aggravated along railroad track than in the adjacent open country, its influence is found to be considerably greater in the case of resurveys along the track than in location or other surveys made before construction. Notwithstanding this fact, appreciable errors, due to atmospheric influences alone, undoubtedly occur in the latter class of surveys, owing to the long sights occasioned by the usual rush in such surveys. Under the extreme atmospheric conditions of the Gulf Coast country, where the above mentioned influences are frequently magnified by excessive humidity, the writer has been compelled to adopt special methods of survey in order to secure satisfactory results. In the above mentioned locality an ordinary flag pole at a distance of 1,000 feet, when viewed through the telescope of an engineer's transit in the middle portion of a hot day, presents a blurred image apparently several inches in width, and with a sight of one-half that length it is often found impracticable to secure a distinct and stationary image. For this reason a suspension in the alinement survey for a few hours during the middle of the hotter days, similar to that required in careful geodetic work, is found necessary in order to secure satisfactory results. In resurveys made for the purpose of readjusting both grades and alinement, such as are usual with extensive ballasting operations, this midday interval may be utilized in running the levels, since satisfactory results may generally be reached by reducing the maximum length of sight to 250 feet, at which distance reliable readings to hundredths of a foot may, as a rule, be taken with a self-reading rod.

Under the extreme conditions above described, the writer has had occasion to develop a system for the resurvey of long tangent lines, which, with proper modifications to suit local requirements, has proven generally satisfactory. It should be stated in giving a brief description of the system just referred to, that no
special claim of priority is made, since many others have doubtless used an equivalent plan for accomplishing the same result. Before proceeding to a presentation of the matter, a word may properly be said concerning the devices which are available to the engineer for the concealment of lateral deflections in tangent lines in process of readjustment. At first thought the simplest plan would seem to be to make such widening of roadbed or shifting of bridges or other track structures as may be required to permit the restoration of a supposed perfect tangent in the original location; and indeed, where extensive work perhaps amounting to reconstruction is in progress, there may often be no reason why a true tangent should not be established, particularly when the deviations are slight, or when distinct summits at which deflections are most effectually concealed do not exist. Except in such cases, however, the means available to the engineer do not usually admit of extensive lateral shifting merely for the above purpose, since the operating value of a true tangent is of course no greater than that of a line containing visible lateral deflections.

In the case of tangents of unusual length which were run in with a poorly collimated or manipulated transit in the location survey, a resurvey often develops the fact that the supposed tangent is in reality an exceedingly flat curve or a succession of such curves in reversed directions, none of them, perhaps, being distinctly visible to even a close observer. Where such curvature exists in a marked degree, it may be thought best to concentrate the deflections into distinct swings at intervals of several miles, but as this usually means little short of reconstruction of a considerable stretch of roadbed, besides giving very unsightly results, the plan is rarely adopted. It has been asserted that attempts at the precise adjustment of track alignment are a sheer waste of time and money, but unquestionably there are occasions when the engineer is open to just criticism if he fails to attend to the finer points of this problem. In the opinion of the writer, the best plan is that in which a careful resurvey of the existing center line of the so-called tangent serves as a basis for the readjustment, the ruling points and rates of deflection being determined in a manner very similar to that used in fixing grade lines. Such a system will now be described.
The track is carefully chained with a 100-foot steel tape, the measurement being made preferably along the tie ends, say 3 or 4 inches to the right of the right hand rail. Eleven chaining pins are used, and instead of indicating the stations by means of stakes, an arrow mark made with white lead on the rail flange opposite the pin is used for this purpose. The number of the station is marked on the rail flange to the right of the arrow, a small pot of white lead and a suitable brush being carried for the purpose. This plan of marking the station on the rail flange has much to commend it, and it should be stated that when properly applied the white lead may be distinguished after a couple of years, unless covered over by oil and dirt. The chaining party thus need not consist of more than three persons, viz.: the front and rear chainmen and the engineer, or a competent assistant who does the marking and records the station numbers of all bridges, road crossings and other track structures, summits when distinct enough to assist in the readjustment, and, in fact, all important features along the line.

Reference has already been made to the use of the midday hours in the leveling operations through a reduction in the length of sight. The adoption of a 250-foot maximum sight under the extreme atmospheric conditions above described led to the use of a special plan in the leveling work, which was found to largely compensate for the loss of time resulting from the shorter sights. This plan consisted in driving a solid bench stake in a secure place at each tenth station. The convenience in the subsequent work of setting ballast grades, as well as the constant checking of levels by means of these bench marks, proved the system to be an excellent one.

The transit party consists of a transitman, a rear flagman and a front flagman, the last named being provided with a flag pole, tacks, pocket tape, hand axe, and a stout shoulder sack containing a supply of hard wood hubs. Commencing at one end of the tangent line, (which will be called station 0 for the sake of simplicity), a hub is driven midway in the space between two ties, where it will be least apt to be disturbed. After setting a tack in this hub to agree with the existing track center, this point is carefully referenced out. This operation is repeated at stations 10 and 20, except that the referencing may perhaps be omitted, provided the track foreman's attention is called to the
stakes so as to avoid disturbing them in the repairs. Now with the rear flag on the hub at station 0 and the transit accurately set over the hub at station 10, double sights are taken to the front flag at station 20, the two sightings being fixed by tacks set in the edge of the tie adjacent to the space in which the hub is located (usually within 8 or 10 inches of it). After repeating the sights as a check, the transitman passes to station 20 as rapidly as possible, the removal of the transit being the signal to the two flagmen to move forward ten stations. Upon reaching station 20, the transitman bisects the space between the two tacks just sighted in, and also carefully marks the existing track center on the same tie edge. He then measures to the nearest hundredth of a foot the distance that the existing center is to the right or to the left of the mean point and records the same in the manner to be described. Now setting the transit over the center hub at station 20, and with back sight at rear flag on hub at station 10, the double tacks are set on tie edge at station 30, adjacent to the center hub, which the front flagman has in the meantime established at the latter station. The party moves forward ten stations, the bisection and measurement at 30 is made by the transitman as above described, and the work thus proceeds indefinitely, the full ten stations being taken as a fixed length of sight, and the back sight being taken on the previous hub. The front flagman is supplied with a memorandum of important bridges and summits or other local features which may act as ruling points in the readjustment, and upon reaching the designated object (generally indicated in the memorandum by the nearest even station) a hub is set and the double tacks are fixed in the adjacent tie edge, after which the front flagman proceeds to the even tenth station as before. In moving forward the transitman stops at the intermediate point and goes through the process already described, except that the transit is not set up at intermediates.

The form of keeping the notes and also the method of reducing and applying them in the readjustment of the line are indicated in Table I, and the "lateral profile" shown in Fig. 1 was made from these notes. This "profile" was originally constructed on Plate "A" profile paper, taking 2,000 feet per inch longitudinally, and 0.40 feet per inch laterally, which scales are convenient for ordinary cases. Columns II and III in Table I contain
### Table I.

**Field Notes and Data for Use in the Readjustment of a Long Tangent.**

<table>
<thead>
<tr>
<th>Station</th>
<th>OLD LINE</th>
<th>READJUSTED LINE</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>DEFL.</td>
<td>PARTIAL</td>
<td></td>
</tr>
<tr>
<td></td>
<td>OLD</td>
<td>TOTAL</td>
<td></td>
</tr>
<tr>
<td></td>
<td>L.</td>
<td>R.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>READJUST.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>L.</td>
<td>R.</td>
<td></td>
</tr>
<tr>
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</tr>
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<td>9.15</td>
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</table>

**Totals are taken with reference to a vertical plank 16 ft. to the left of and parallel to the line 0-10.**

**Bridge No. 341, 42 ft. long.**

**Bridge No. 342, 70 ft. long.**

**Well-defined Summit.**

**Summit.**
READJUSTMENT OF LONG RAILROAD TANGENTS.
the deflections measured in the field in the manner above described, the fractional stations and the corresponding notes being enclosed in parentheses. Column IV contains the continued sum of the deflections recorded in II and III, the results being in reality the rates of inclination of the corresponding back sights to the datum plane. Considering this fact, the method by which the fractional "partials" are obtained is easily seen. Column V contains the totals with reference to a vertical plane 10.00 feet to the left of and parallel to the line 0-10 and corresponds to the "elevation" column in the common system of level note keeping. The datum plane is thus assumed to one side in order to avoid totals of opposite signs. The process of making the readjustment to agree with the ruling points, given in columns VI to IX inclusive, is essentially the same as that of laying grade lines and, being clearly shown in Fig. 1, no description seems necessary. The notes may be checked in a manner similar to that used in level notes. Thus the algebraic sum of Columns II and III (omitting intermediates) should be equal to the "partial" for station 200 given in Column IV, and the algebraic sum of Column IV should be equal numerically to the difference between the first and last totals of Column V.

An examination of the method of working up the totals will show that the results are practically the same as would be obtained by prolonging the datum line indefinitely and measuring the deflections direct, the approximation usually being so slight as to require no consideration. In the case of a tangent deflecting continuously in one direction to an extreme degree, it may be advisable ultimately to assume a new datum plane. With broken or rolling country it will generally be impracticable to use the uniform length of sight as above described, but modifications of an obvious character may be made without affecting the efficiency of the system.

If it is desired to record the angular deflections in the tangent, it is sufficient to use the value of one second of arc, .000005 (more exactly .0000048) which is easily remembered as "five naughts and a five"; or one minute of arc, .0003 (more exactly .00029) which can be remembered as "three naughts and a three." It is thus seen for example, that 0.01 feet subtends an angle of 2 seconds at a distance of 1000 feet.
APPENDIX II

RAILROAD CROSSING FROGS

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From The Technograph No. 9.

1894-5.

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154
RAILROAD CROSSING FROGS.

By Wm. D. Pence, Assistant Professor of Civil Engineering.

The measurement of the angle for a railroad crossing frog is usually a comparatively simple matter. Yet it is found that under conditions which prevail in most large railroad centers, the collection of complete data required in ordering a crossing frog may demand special skill and experience on the part of the engineer. Among the complicating circumstances encountered in most large cities are crowded railroad or street traffic, curved alinement of the tracks, and contiguity of other crossings. In preparing the order for a crossing frog, it is the custom of some engineers to provide a more or less elaborate drawing showing the details of the frog. This procedure is doubtless necessary in many instances, but in a large majority of cases it is sufficient to prepare a simple and clear centerline drawing, supplemented by a tabulated statement of the data required by the maker of the frog. In collecting the data to accompany the order for a crossing frog, the following items require due attention:

(1) The Gage of each Track involved in the Crossing.—In most cases the intersecting tracks will be of the same gage, but this point should be carefully tested by actual measurement. Among the most probable sources of error in this regard are the confusing of the standard gage of 4 ft. 8 1/2 ins. with the less common gage of 4 ft. 9 ins., and the failure to observe the widening on sharp curves.

(2) The Alinement of each Track.—In newly located crossings, exact refinements in the matter of alinement may properly be given precedence over the question of economy in cutting rails, but in the renewal of old crossing frogs the latter consideration is usually given the more weight, particularly where connection with or close proximity to other frogs may serve to fix in a rigid manner the position of one or both of the tracks. Where the center lines are not to be disturbed in renewing the crossing, it is necessary to consider the alinement little, if any, beyond the outermost limits of the set of frogs concerned. In fact, with crossings on curved tracks the use of centers as much as 100 ft. distant from the intersection to determine the direction of the tangent line, may lead to a perceptible
RAILROAD CROSSING FROGS.

misfit in the frog, owing to a lack of uniformity in the curvature within the limits taken. Ordinarily the alinement of the center lines need not be considered more than 20 or 30 ft. either way from the point of intersection. An exception to the above rule is found occasionally where the old frog has been dragged out of line on one or both lines of railroad by the "creeping" of the rails, a phenomenon which is usually, and no doubt correctly, ascribed to unbalanced traffic. The last named defect of course looks most unsightly on tangent track, but it may be sufficiently aggravated in curved tracks as well to demand periodical correction by driving the rails back or substituting rails of other lengths as may be required. In chronic cases of worn-out crossing frogs, which it must be admitted are far too common in this country, it may often be the wisest plan to re-adjust the alinement regardless of rail connections, especially if rail renewals are in contemplation on either road.

(3) The Angle of Intersection of the Center Lines.—The angle required is that made by the tangent lines at the point of intersection, and in the case of curved tracks this angle is, of course, equal to that between the radii to the common point. In taking the field notes, a sketch should be made showing in an unmistakable manner the position of the measured angle with relation to the cardinal points and surrounding objects and also indicating distinctly the curvature of the tracks, if the tracks are not on tangent. It is an excellent practice, and certainly a safe one, to measure supplementary angles with the transit and to check these measurements by means of a metallic or steel tape before leaving the site, the two values to agree within a minute or so. The degree of curve should also be verified by measuring the tangent offset, and centers should be established within the limits considered, for subsequent use of the trackmen in putting in the frog. These centers may also serve a valuable purpose in case of a dispute in relation to the fitting qualities of the new frog after its delivery at the site.

(4) Rail Connections.—This point is obviously affected by the action taken in relation to the alinement (2). In new crossings, the lengths of the wing rails may, as a rule, be fixed arbitrarily, but usually in renewing crossings the old length of rail, out to out in each direction, is taken as a ruling dimension to avoid cutting rails. The last named rule is observed with special strictness in reference to the rails on the foreign road. One reason for its observance is that it prevents or reduces possible delay to traffic when the new frog is put in place.
(5) **Rail Section.**—Where the weights of rail differ in the two tracks, it is the usual custom to manufacture the crossing from rail to fit the heavier section. When the sections are widely different in height, it is good practice to insert a rail of the heavier section adjoining the frog in either direction on the road having the lighter rail in order to reduce the effect of the wheels passing over this joint. It is necessary to provide shims and perhaps special chairs and compromise splices where the difference of heights of the two rails is considerable. It is, of course, desirable to secure an exact section of the rail from which the frog is to be made, but it is often necessary and usually sufficient to give only the principal dimensions of the rail and its weight, with perhaps its brand.

(6) **Spacing of Bolt Holes.**—The bolt holes may, of course, be spaced to conform to different requirements on the two lines.

(7) **Inside Flange Gage of the Wheels.**—It is unnecessary to give consideration to this item unless one of the lines of road concerned in the crossing has rolling stock of an unusual type as regards the wheels, for the reason that the maker always constructs the crossing with the wheel flange clearance to conform to adopted standards. The minimum clearance between the wheel flanges on the motive power and cars ordinarily used on logging and similar tramways is considerably less than that on the usual type of rolling stock. The difference is not so great, however, as to prevent the use of a crossing frog ordered for such a tramway in which this point was overlooked; for, as a rule, sufficient clearance may be gained by trimming or chipping off a strip of the head of each guard rail on the tramway side of the crossing.

In most cases the engineer is not called upon to determine any angle, except that of the intersection of the center lines, which he does instrumentally. It sometimes happens, however, that a new set of frogs arrives at the site of the crossing, and owing to the dilapidated condition of the old crossing or other cause, a preliminary trial by superimposing the new over the old, leads the trackman to believe that an error has been made in the new frog. Naturally and properly the burden of the proof and responsibility falls upon the person who measured the angle and secured the data which accompanied the order for the crossing. In such cases of dispute it is highly essential that the engineer be able to compute promptly and positively the angles of the several rail intersections and the other essential dimensions of the set of frogs; for in his investigation of the matter the engineer is called upon to verify, not only his own
RAILROAD CROSSING FROGS.

measurements according to the centers which he is presumed to have established, but also the work of the frog maker. If one or both tracks chance to be on tangent, the latter operation is of an obviously simple character; but there is reason to believe that aside from those engaged directly in the manufacture of crossing frogs, comparatively few engineers are familiar with the more complex problem of a crossing of two curved tracks. The writer therefore ventures to transcribe from his private notes the following solution of the problem, which was envoled and frequently used in the exigences of railroad service some years ago. For the sake of completeness, the simple case of the crossing of two tangent tracks will be given.

1. **Both Tracks on Tangent.** Fig. 1.

Let $F$ — the angle of intersection of the center lines.

$F_1$, $F_2$, $F_3$, $F_4$ — the respective gauge-line intersection angles.

$g$, $G$ — the respective gages of track.

Then, in Fig. 1, $F = F_1 - F_2 - F_3 - F_4$.

1. $F_1 F_2 - F_4 F_3 = \frac{g}{\sin F} \cot \theta$.

2. $F_2 F_4 - F_1 F_3 = \frac{G}{\sin F} \cot \theta$.

If $G = g$:

3. $F_1 F_2 - F_4 F_3$.

II. **One or Both Tracks on Curve.** Figs. 2, 3 and 4.

With the view to simplify the solution of the problem and to facilitate the application of the resulting formulas in practice, the figures have been constructed upon the assumption that the center, $B$, of the flatter curve, lies always to the right of the center, $A$, of the sharper curve. The symmetrical duplications of the crossings shown in the figures above and below the line $AB$, serve to illustrate all possible cases of the problem and thus assist in the comprehension and use of the method deduced. With such relative positions for the centers of the two circles, the length, $BF$, of the longer radius may be conceived to vary between the two limits $E = r$, and $R = \infty$.

The latter limit is illustrated in Fig. 2, in which the center, $B$, lies at an infinite distance to the right. Fig. 3 shows the case with the two tracks curved in the same direction, and Fig. 4 shows the curvature in contrary directions. By considering always the interior radial angle instead of the corresponding tangential intersection angle, the two being equal, and using the auxiliary quantity $V$, a set of comparatively simple formulas may be obtained, which covers the two cases alike. It should be observed in Fig. 4 that according to the
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basis here assumed, the angle of the intersection of the two curves in opposite directions is greater than 90°, while the angle is less than a right angle when the curvatures agree in direction.

For the sake of simplicity, the several parts of the flatter curve are represented in the figures and the work below by capital letters, and the corresponding quantities for the sharper curve are indicated by lower case letters. Thus, the outer gage-lines are represented by O'OO" and o'oo", the inner gage-lines by I'II" and i'i"", and the center lines by C'CC" and c'ce"", respectively.

NOMENCLATURE.

Let $R = \text{radius of center line of the flatter curve.}$

Let $R_i = \text{radius of outer gage-line of the flatter curve.}$

Let $R_5 = \text{inner " " " " inner.}$

$\rho = \text{radius of center line of the sharper curve.}$

$L = \text{radius of outer gage-line of the sharper curve.}$

$L_5 = \text{inner " " " " inner.}$

$F = \text{angle of intersection of } C'C'C'' \text{ with } c'c'e''$ included between $R$ and $\rho$.

$F_1 = \text{of intersection of } 0'0'0'' \text{ with } i'i'i''$ included between $R_3$ and $\rho_3$.

$F_2 = \text{of intersection of } 0'0'0'' \text{ with } o'oo''$ included between $R_3$ and $r_3$.

$F_3 = \text{of intersection of } I'I'I'' \text{ with } o'oo''$ included between $R_3$ and $\rho_3$.

$F_4 = \text{of intersection of } I'I'I'' \text{ with } i'i'i''$ included between $R_3$ and $\rho_3$.

$V = \text{Ce = distance between left vertices (on the line joining the centers) of the circles which intersect in the point } F.$

$V_1 = \text{corresponding distance for the point } F_1.$

$V_2 = Oo = \text{" " " " " } F_1.$

$V_3 = Io = \text{" " " " " } F_2.$

$V_4 = li = \text{" " " " " } F_3.$

$G = \text{gage of the flatter curve.}$

$g = \text{" " " " } \text{sharper " " " }$.

The designations of the following angles were omitted from the figures to avoid confusion:

$a = \text{FAB} = \text{interior angle between } r \text{ and the line } AB.$

$a_1, a_2, a_3, a_4 = \text{corresponding angles for the radii } r_1, r_2, r_3, r_4.$

$b = \text{FBA} = \text{interior angle between } R \text{ and the line BA.}$

$b_1, b_2, b_3, b_4 = \text{corresponding angles for the radii } R_1, R_2, R_3, R_4.$
RAILROAD CROSSING FROGS.
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1. One track on curve and the other on tangent. Fig. 2.

The track C'C" being on tangent, gives $R = \infty$. Having determined the angle of intersection $F'$ of the center lines, we have

$$V - r \text{ vers } F \quad \ldots \ldots \quad (5)$$

and

$$\text{vers } F_1 = \frac{V_1}{r_1} \quad \ldots \ldots \quad (6)$$

$$\text{vers } F_2 = \frac{V_2}{r_2} \quad \ldots \ldots \quad (7)$$

$$\text{vers } F_3 = \frac{V_3}{r_3} \quad \ldots \ldots \quad (8)$$

$$\text{vers } F_4 = \frac{V_4}{r_4} \quad \ldots \ldots \quad (9)$$

The values of the respective radii $r_1$, etc., and distances $F_1$, etc., to be substituted in (6), (7), (8) and (9) are determined by inspection from Fig. 2. Table I. gives these terms for unequal gages of track, and Table II. for equal gages.

**TABLE I.**

Values for Substitution in Equations (6), (7), (8) and (9).

Gages unequal. $G$—gage of tangent track; $g$—gage of curved track.

<table>
<thead>
<tr>
<th>Angle</th>
<th>Intersecting Lines</th>
<th>Radius</th>
<th>Auxiliary Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F'$</td>
<td>$C'C''$, $c'c''$</td>
<td>$r = r$</td>
<td>$V - V'$</td>
</tr>
<tr>
<td>$F_1$</td>
<td>$O'O''$, $i'i''$</td>
<td>$r_1 = r - \frac{1}{2} g$</td>
<td>$V_1 - V_1 - \frac{1}{2} (G + g)$</td>
</tr>
<tr>
<td>$F_2$</td>
<td>$O'O''$, $o'o''$</td>
<td>$r_2 = r + \frac{1}{2} g$</td>
<td>$V_2 - V_2 + \frac{1}{2} (G - g)$</td>
</tr>
<tr>
<td>$F_3$</td>
<td>$I'I''$, $o'o''$</td>
<td>$r_3 = r + \frac{1}{2} g$</td>
<td>$V_3 - V_3 + \frac{1}{2} (G + g)$</td>
</tr>
<tr>
<td>$F_4$</td>
<td>$I'I''$, $i'i''$</td>
<td>$r_4 = r - \frac{1}{2} g$</td>
<td>$V_4 - V_4 - \frac{1}{2} (G - g)$</td>
</tr>
</tbody>
</table>

**TABLE II.**

Values for Substitution in Equations (6), (7), (8) and (9).

Gages of track equal. $G = g$.

Intersecting lines and radii as in Table I.

<table>
<thead>
<tr>
<th>Angle</th>
<th>Auxiliary Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F$</td>
<td>$V - V'$</td>
</tr>
<tr>
<td>$F_1$</td>
<td>$V_1 - V_1 - g$</td>
</tr>
<tr>
<td>$F_2$</td>
<td>$V_2 - V'$</td>
</tr>
<tr>
<td>$F_3$</td>
<td>$V_3 - V_3 + g$</td>
</tr>
<tr>
<td>$F_4$</td>
<td>$V_4 - V'$</td>
</tr>
</tbody>
</table>
Having computed the values of the several gage-line intersection angles, the distances between points of intersection are obtained by the following formulas:

\[
F_1 F_4 = \frac{r_4 \sin F_3}{r_3 \sin F_1} \quad \ldots \quad (10)
\]

\[
F_3 F_4 = \frac{r_3 \sin F_3}{r_4 \sin F_4} \quad \ldots \quad (11)
\]

\[
F_5 F_6 = 0.000291 \cdot r_5 (F_5 - F_6) \quad \ldots \quad (12)
\]

\[
F_1 F_4 = 0.000291 \cdot r_1 (F_1 - F_4) \quad \ldots \quad (13)
\]

Also, the bending ordinates for the curved rails may be determined by

mid-ordinate of \( F_5 F_6 - r_5 \) vers \( \frac{1}{2} (F_3 - F_2) \) \ldots (14)

mid-ordinate of \( F_1 F_4 - r_1 \) vers \( \frac{1}{2} (F_1 - F_4) \) \ldots (15)

2. Both tracks on curves. Figs. 3 and 4.

In the triangle \( FAB \), Figs. 3 and 4, the angle \( F \) and the radii \( R \) and \( r \) are determined instrumentally. Then

By trigonometry,

\[
\tan \frac{1}{2} (a-b) = \frac{R - r}{R + r} \cdot \tan \frac{1}{2} (a+b)
\]

in which

\[
a + b = 180^\circ - F
\]

Then

\[
\tan \frac{1}{2} (a-b) = \frac{R - r}{R + r} \cdot \cot \frac{1}{2} F
\]

and

\[
a = \frac{1}{2} (a + b) + \frac{1}{2} (a - b)
\]

\[
b = \frac{1}{2} (a + b) - \frac{1}{2} (a - b)
\]

Having determined the angles of the triangle, the distance between the centers is found by

\[
AB = r \cdot \frac{\sin F}{\sin b} = r \cdot \sin F \cdot \csc b \quad \ldots \quad (18)
\]

By inspection of Figs. 3 and 4, it is seen that

\[
V = AB - r - R \quad \ldots \quad (19)
\]

*Are \( 1 - 0.000291 \). Although the angle of intersection of center lines will ordinarily be measured only to the nearest minute, the computed values of angles to be used in fixing the rail intercepts should be determined at least to the nearest tenth minute, particularly when the radii are large.
### TABLE III.

**Values for Substitution in Equations (21), (22), (23) and (24).**  
Gages of track unequal.  
$G$—gage of flatter curve; $g$—gage of sharper curve.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$F$</td>
<td>$C' CC''$, $c' cc''$</td>
<td>$R - R$</td>
<td>$r - r$</td>
<td>$V = V$</td>
<td>$S - R - r + \frac{1}{2} V$</td>
</tr>
<tr>
<td>$F_1$ (21)</td>
<td>$0' 00''$, $i' ii''$</td>
<td>$R_1 = R + \frac{1}{2} G$</td>
<td>$r_1 - r - \frac{1}{2} g$</td>
<td>$V_1 = V - \frac{1}{2} (G - g)$</td>
<td>$S_1 = S + \frac{1}{4} (G - g)$</td>
</tr>
<tr>
<td>$F_2$ (22)</td>
<td>$0' 00''$, $o' oo''$</td>
<td>$R_2 = R + \frac{1}{2} G$</td>
<td>$r_2 - r - \frac{1}{2} g$</td>
<td>$V_2 = V - \frac{1}{2} (G - g)$</td>
<td>$S_2 = S + \frac{1}{4} (G - g)$</td>
</tr>
<tr>
<td>$F_3$ (23)</td>
<td>$1' II''$, $o' oo''$</td>
<td>$R_3 = R - \frac{1}{2} G$</td>
<td>$r_3 - r - \frac{1}{2} g$</td>
<td>$V_3 = V + \frac{1}{2} (G - g)$</td>
<td>$S_3 = S - \frac{1}{4} (G - g)$</td>
</tr>
<tr>
<td>$F_4$ (24)</td>
<td>$1' II''$, $i' ii''$</td>
<td>$R_4 = R - \frac{1}{2} G$</td>
<td>$r_4 - r - \frac{1}{2} g$</td>
<td>$V_4 = V + \frac{1}{2} (G - g)$</td>
<td>$S_4 = S - \frac{1}{4} (G - g)$</td>
</tr>
</tbody>
</table>
RAILROAD CROSSING FROGS.

By trigonometry, 
\[ \text{vers } F = 2 \frac{(s - R) (s - r)}{Rf} \]

in which 
\[ s = \frac{1}{2} (R + r + \text{AB}) = R + \frac{1}{2} V \]
\[ s - R = \frac{1}{2} V \]
\[ s - r = R - r + \frac{1}{2} V \]

so that 
\[ \text{vers } F = \frac{V (R - r + \frac{1}{2} V)}{Rf} \]  \( \ldots \ldots \ldots \)  (20)

The relation expressed in (20) is true of each of the intersections if the terms involved be assigned proper values. Hence the following may be written for the several gage-line intersections:

\[ \text{vers } F_1 = \frac{V_1 (R_1 - r_1 + \frac{1}{2} V_1)}{R_1 r_1} \]  \( \ldots \ldots \ldots \)  (21)
\[ \text{vers } F_2 = \frac{V_2 (R_2 - r_2 + \frac{1}{2} V_2)}{R_2 r_2} \]  \( \ldots \ldots \ldots \)  (22)
\[ \text{vers } F_3 = \frac{V_3 (R_3 - r_3 + \frac{1}{2} V_3)}{R_3 r_3} \]  \( \ldots \ldots \ldots \)  (23)
\[ \text{vers } F_4 = \frac{V_4 (R_4 - r_4 + \frac{1}{2} V_4)}{R_4 r_4} \]  \( \ldots \ldots \ldots \)  (24)

The respective values of the radii and the auxiliary distances to be substituted in (21), (22), (23) and (24) are given in Tables III and IV.

**TABLE IV.**

VALUES FOR SUBSTITUTION IN EQUATIONS (21), (22), (23) and (24).

Intersecting lines and radii as in Table III.

Gages of track equal.  \( G = g \).

<table>
<thead>
<tr>
<th>Angle.</th>
<th>Auxiliary Distance</th>
<th>Term ( S - R - r + \frac{1}{2} V )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( F )</td>
<td>( V = V )</td>
<td>( S - R - r + \frac{1}{2} V )</td>
</tr>
<tr>
<td>( F_1 ) (21)</td>
<td>( V_1 = V - g )</td>
<td>( S_1 = S - \frac{1}{2} g )</td>
</tr>
<tr>
<td>( F_2 ) (22)</td>
<td>( V_2 = V )</td>
<td>( S_2 = S )</td>
</tr>
<tr>
<td>( F_3 ) (23)</td>
<td>( V_3 = V + g )</td>
<td>( S_3 = S - \frac{1}{2} g )</td>
</tr>
<tr>
<td>( F_4 ) (24)</td>
<td>( V_4 = V )</td>
<td>( S_4 = S )</td>
</tr>
</tbody>
</table>

In order to determine the distances between the points of intersection of gage-lines, and the ordinates for bending the rails, it is necessary to compute the values of the angles \( a_1, b_1, a_2, b_2 \), etc.

*Note that when the curvatures are in opposite directions, Fig. 4, the value of \( F \) exceeds 90°; the values of the several angles in that case may be obtained by remembering that vers 90° = 1, and vers 180° = 2.
RAILROAD CROSSING.FROGS.

In each of the triangles \( F_1 \) AB, \( F_2 \) AB, etc., one angle and the sides are known, so that

\[
\sin \alpha_1 = \frac{R_1 \sin F_1}{AB} \quad \ldots \ldots \quad (25)
\]

\[
\sin \alpha_2 = \frac{R_2 \sin F_2}{AB} \quad \ldots \ldots \quad (26)
\]

\[
\sin \alpha_3 = \frac{R_3 \sin F_3}{AB} \quad \ldots \ldots \quad (27)
\]

\[
\sin \alpha_4 = \frac{R_4 \sin F_4}{AB} \quad \ldots \ldots \quad (28)
\]

In like manner, \( \sin \beta_1 = r_1 \frac{\sin F_1}{AB} \quad \ldots \ldots \quad (29) \)

\[
\sin \beta_2 = r_2 \frac{\sin F_2}{AB} \quad \ldots \ldots \quad (30)
\]

\[
\sin \beta_3 = r_3 \frac{\sin F_3}{AB} \quad \ldots \ldots \quad (31)
\]

\[
\sin \beta_4 = r_4 \frac{\sin F_4}{AB} \quad \ldots \ldots \quad (32)
\]

And, as a check,

\[
a_1 + b_1 + F_1 = 180^\circ \quad \ldots \ldots \quad (33)
\]

\[
a_2 + b_2 + F_2 = 180^\circ \quad \ldots \ldots \quad (34)
\]

\[
a_3 + b_3 + F_3 = 180^\circ \quad \ldots \ldots \quad (35)
\]

\[
a_4 + b_4 + F_4 = 180^\circ \quad \ldots \ldots \quad (36)
\]

Then by inspection of Figs. 3 and 4,

\[
F_1 F_2 = .000291 \, R_1 (b_1 - b_1) \quad \ldots \ldots \quad (37)
\]

\[
F_2 F_3 = .000291 \, r_2 (a_2 - a_2) \quad \ldots \ldots \quad (38)
\]

\[
F_3 F_4 = .000291 \, R_3 (b_3 - b_4) \quad \ldots \ldots \quad (39)
\]

\[
F_4 F_4 = .000291 \, r_4 (a_4 - a_4) \quad \ldots \ldots \quad (40)
\]

And the mid-ordinates are as follows:

\[
M \text{ for } F_1 F_2 - R_1 \, \text{vers } \frac{1}{2} (b_2 - b_1) \quad \ldots \ldots \quad (41)
\]

\[
\text{“ “ } F_2 F_3 - r_2 \, \text{vers } \frac{1}{2} (a_2 - a_3) \quad \ldots \ldots \quad (42)
\]

\[
\text{“ “ } F_3 F_4 - R_3 \, \text{vers } \frac{1}{2} (b_3 - b_4) \quad \ldots \ldots \quad (43)
\]

\[
\text{“ “ } F_4 F_4 - r_4 \, \text{vers } \frac{1}{2} (a_4 - a_4) \quad \ldots \ldots \quad (44)
\]
3. Discussion of Formulas.

It may be shown as follows that Fig. 2 is merely a special case of the general problem: Eq. (20) may be written thus

\[ \text{vers} \, F = \frac{V}{r} - \frac{V(r - \frac{1}{2} r)}{Rr} \]

Substituting in above the value \( R = \infty \)

\[ \text{vers} \, F = \frac{V}{r} \] which is eq. (5) transposed.

Putting \( R = r \) in (19), it is found that \( V = AB \), and the same value substituted in (20) gives

\[ \text{vers} \, F = \frac{V}{2r^2} \] But \( \text{vers} \, F = 2 \sin^2 \frac{1}{2} F' \), so that

\[ V = AB = 2 \, r \, \sin \frac{1}{2} F' \] \hspace{1cm} (45)

In this case of equal degrees of curve, the two radii to the point of intersection of the center lines are the equal sides of an isosceles triangle, and the line bisecting the radial angle \( F \) is a line of symmetry to the crossing, passing through the points \( F_1, F \) and \( F_2 \), and bisecting \( AB \) at right angles.

The condition for a right angled crossing is found by placing \( \text{vers} \, F = 1 \) in (20), from which

\[ V = \sqrt{R^2 + r^2} - (R - r) \] \hspace{1cm} (46)

If \( R = r \), (46) becomes

\[ V = r \sqrt{2} = 2 \, r \, \sin 45^\circ \] \hspace{1cm} (47)
APPENDIX III.

EXPERIENCE WITH CREEPING RAILS.

From the Ninth Annual Report of the Illinois Society of Engineers and Surveyors.
EXPERIENCE WITH CREEPING RAILS.

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The two-and-a-quarter-mile width of Galveston Bay, between Virginia Point and Galveston Island on the Gulf Coast is spanned by two single track pile bridges, one of which belongs to the International and Great Northern and the other to the Gulf, Colorado and Santa Fe Railway. As it is the purpose of this paper to present a few observations relative to the creeping or longitudinal movement of the rails upon the last named bridge, a brief description of the structure itself may not be without interest. A view of the bridge from the rear end of a passing train is by no means reassuring, and condemnation on first sight has been the act of more than one new official. Yet, it is safe to predict that almost any engineer of judgment and experience, into whose hands might be placed executive charge of the bridge department of this road, would, at the end of a year of careful observation and study of the conditions, conclude to do as others before him had done, unless, perchance, the means available for maintenance of the structure were far in excess of the amount hitherto allowed. The apparent weakness referred to consists of, (1) the rapid destruction of the piling by the teredo or sea-worm, and (2) the unusually frail type of deck. The latter is a direct result of the former on account of the frequent necessity of removing portions of the deck in making the heavy pile renewals. The deck consists merely of 2 in. x 8 in. x 6 ft. ties spaced 2 ft. centre to centre and the ends being flush with the outside edges of 12 in. x 14 in. stringers, all of long-leaf pine. There are no guard rails of any kind, but by rigidly controlling the speed of trains, derailments have been exceedingly rare and the maximum degree of safety possible in the absence of special guards has been attained.

From the date of completion of the bridge in 1876 up to September, 1888, 56-lb. iron rail was used, and during the cotton season, that is from September to January, inclusive, much trouble was experienced by the rails creeping southward in the direction of heavier traffic, a phenomenon which in years past has been quite fully discussed. This trouble was most marked at the two ends of a draw span located near the middle of the bridge, the rails jamming at the north end and leaving a gap at the south end of the draw, which made
it necessary to keep constantly at hand a number of short pieces of rail or "dutchmen," as they are called. During September, 1888, the iron rail was replaced by Scranton steel rail of the Standard Pennsylvania 60-lb. section, height 4½ in. and 4 in. base. Just previous to relaying the rail, the writer made a series of observations for the purpose of determining the amount of the rail movement under the existing traffic and also to decide upon the proper allowance for temperature expansion. It may be of interest to state that it was found that a train of forty loaded freight cars caused a movement of the rail in the direction of the train of about 1½ ins. and, as I now recall the figures, the movement was about the same amount for double that number of empty cars. Although the investigation was made before the cotton rush had fairly begun, it indicated quite clearly a line of action, which, when subsequently put into practice, proved to be wise in almost every particular.

After a brief discussion it was decided to lay the steel with ¼ in. expansion and to thoroughly secure each joint by full-spiking the slots in the angle plates. As the ties were but 2 ins. thick, it was, of course, necessary to spike into the stringer, for which purpose requisition was made for a sufficient number of 5-16x5-16x7 in. track spikes with wedge points turned, sometimes called the "timber" spike; but as the order was not filled in time, ¼ by 9 in. round bolts, made by cutting the ordinary 18 in. drift bolt in two, were substituted for spikes, 11-16 in. holes being first bored. The angle plates were slotted for suspended joints, but a 2×8×16 in. block was placed between the ties under each joint.

During the cotton seasons of 1888 and 1889, no creeping whatever took place, but during the summer of 1890, a new bridge foreman began to remove the spiking on Bay Bridge under a misapprehension of a general order which prohibited the spiking of slots on bridges. This action was not observed at the time, inasmuch as the removal was carried on gradually and without system. By the time the 1890 cotton rush was well started the number of spikes which had been drawn was such that the creeping tendency under the unbalanced tonnage overcame the resisting power of the remaining anchorage, making it imperatively necessary to immediately remove all slot spiking.

In many joints the slot bolts were bent over and the angle plates actually mounted them, making the track very dangerous for passing trains. As soon as the spiking was removed the old trouble at the draw span was renewed and within thirty days the movement at the north end of the draw span had reached 9 ft. in the west and 13 ft. in the east rail, a portion of the difference being due to the insertion of additional rail on the east side at the north end of the trestle on account of the failure of a joint at that point. The latter trouble first developed during a period of cold weather, which occurred two or three weeks after the spikes had been drawn. It was found that
most of the joints north of the draw had crept open the full amount equal to about $\frac{1}{4}$ in. per joint, and that in this condition the enormous strain due to the contraction during cold nights had bent the track bolts in a number of the joints near the north end of the bridge until these joints were opened as much as $1\frac{1}{4}$ ins., several being as much as $1\frac{1}{2}$ ins. During a week or more of the coldest weather a joint failed almost every morning just before daybreak, the fragments of the bolts being projected to considerable distances. Immediately following this came a period of warm weather which produced an effect quite different from that just described. Investigation showed that all the joints (about 200 joints of $\frac{1}{4}$ in. each) south of the draw had closed up, requiring the addition of four foot pieces at the draw span. The continuous action of the sun heat during several days, with no provision for expansion, caused several quite noticeable swings or "sun kinks" as they are very properly called; and while the trouble at the north end had required the addition of rail, that at the south end of the bridge made it necessary to substitute shorter rails, and furthermore while the former seemed worse on the east side, the latter gave most trouble in the west rail.

After some little discussion in which the investigation and report made previous to laying the steel was brought to light, it was decided to begin at the north end of the bridge and restore the original conditions, using the turned-point timber spike, however, instead of the round bolts. The latter was done as promptly and systematically as possible with the forces available. The writer is not informed as to the action of the rail during the cotton seasons of 1892 and 1893, but the experience of previous seasons, already described, indicates that with proper care in maintaining the slot spiking, no further trouble need be feared. It should be remarked that an objection to the plan adopted is the liability to admit moisture to the heart of the stringer and thus hasten its decay, in which connection, however, it is but just to state that the damage, identical in character to that just mentioned, which the stringers sustained by the dragging out of spikes in the path of the creeping angle plates, was appreciably greater than that due to permanent slot-spiking.

It should have been stated that the rail movement was not in any manner due to the grade line of Bay Bridge, as it is level throughout its length. In this connection the writer recalls another instance where unbalanced traffic caused a movement of the rails sufficient to drag the entire deck of a 400 ft. framed trestle a distance of some 8 inches up a one per cent grade, nearly resulting in the failure of the structure. In this case the slots were not spiked on the bridge, but the angle-plates caught the spikes of adjoining ties.

In conclusion it may be of interest to briefly mention one or two instances of rail creeping which have occurred elsewhere.
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Perhaps the best known case is that of the St. Louis Bridge, which was ably described and discussed by Prof. J. B. Johnson, some 10 years since. According to the data collected in 1883, the average movement per rail of the two tracks on St. Louis Bridge was 401 ft., or more than a foot per day. On the bridge proper, which rises 5 ft. at the center of its 1600 ft. length, the rate of creeping east and west was found to be exactly proportional to the traffic in the two directions, but upon the 2500 ft. approach at the east end, the effect of the 80 ft. per mile gradient upon the rail movement was quite apparent. At the time mentioned a force of eight men was required to substitute pieces of rail of the proper length at three points on the structure, viz.:—at the eastern entrance, at the eastern abutment, and at the western abutment. Of some seven explanations of the trouble assigned at the time, that proposed by Prof. Johnson, based upon the deflection of the rail itself, best accords with the observed action of the rail, besides which it has been clearly proven experimentally. Another instance of creeping rails, is that of the Harrisburg Bridge on the Pennsylvania Railroad, over the Susquehanna. It was originally a single track bridge and the creeping occurred with unbalanced traffic, the rail moving four feet or more. By using wide flanged angle plates with four slots to the joint, thoroughly spiked, the trouble ceased entirely, not only for single track but later with double track service.

While the prevention of rail creeping on the road bed proper usually presents fewer difficulties than upon the bridge, there are instances of extreme elasticity in the road bed in which the creeping tendency exists to an extraordinary degree. It will suffice to mention the case of a bog or quagmire across which the Western Division of the Canadian Pacific Railway is located. The trouble from creeping rails is limited to a space of about three-quarters of a mile east and about a mile west of a small bridge at the foot of a grade in both directions. The roadbed across this bog is so elastic that a passing train causes it to yield about six ins. and a series of waves of about the same height is produced over the bog in the vicinity of the train. In warm weather the rail will often run as much as 12 ins. under an ordinary train and with a consolidation engine, hauling 35 cars, this track has crept 26 ins. in the direction in which the train was moving, three consecutive trains in the same direction often being sufficient to open all the joints on one side and close them on the other side of the bridge above mentioned. It is necessary to surface and line this stretch of track once a week, and the bolt repairs require a box of bolts per month. Cinder ballast is used and it preserves the line and surface fairly well, but does not appreciably reduce the creeping. It is found necessary to omit the spiking in the tie on each side of every joint on account of
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the danger of those ties being dragged out of place by the moving angle plates and thus destroying the gage at such points.

As a remedy under these extreme conditions it was proposed "to use 12 ft. ties, 40 in. angle bars, and to cut a slot in alternate sides of the rail at every tie as a means of holding the rail in position," but no information is at hand as to the action taken and the results secured in the case.

Efforts have been made to control the creeping tendency of rails by special anchorage devices at intervals and leaving intermediate joints unspiked, but it is the writer's belief that success in this matter will be measured by the extent to which the anchorage of individual joints or rails is accomplished.