a 1-ft. radius at points one-tenth of the radius apart, measured along the tangent from the P. C. It will readily be seen that for any other radius the table will apply if every figure in the table is multiplied by the radius of the desired curve.

TABLE XI.—Table of offsets from tangent for radius of 1 ft.

[All measurements are in decimal parts of the radius.]

Tan. Dist., ft....	.1	.2	.3	.4	.5	.6	.7	.8	.9
Offset, ft.........	0.0050	0.0202	0.0461	0.0835	0.1340	0.200	0.2859	0.400	0.5641

Method of use.—Having given the radius of desired curve, multiply each number in the table by its radius in feet and make a new table similar to the above. The figures in the lower line are then the perpendicular offsets from the tangent to the curve at points along the tangent whose distances from the P. C. are shown in the upper line.

In many cases laying out half the curve from the P. C. and the other half from the P. T. will give the best results, since the perpendicular offsets will be shorter than when all points are located from one end.

61. **To locate a curve by offsets from the chords produced.**—Having determined R, assume some length of chord, C′, equal to about 0.2 R, but less than 100 ft., and from Table XII find the corresponding offset from the tangent t for this length of chord. From the P. C. as a center, strike an arc across the tangent produced, using for a radius a chain whose length is C′, or Aa in fig. 29. Find the point on this arc a perpendicular distance, t, from the tangent. This is the point a on the curve. As shown in fig. 29, produce Aa, the distance C′ to b', strike the arc $b'b$, with a radius C′ from a as a center. Strike an arc with a radius $b'b = 2t$ from b' as a center. The intersection of these two arcs is b, a new point in the curve. Produce ab, a distance C′, to c' and strike the arc $c'c$, with C′ as a radius and b as a center. From c', with $2t$ as a radius, strike an arc, and where it intersects the previous arc is c, a new point in the curve. Proceed in a similar manner until a point is reached where the distance to P. T. is less than C′, the chord distance used.

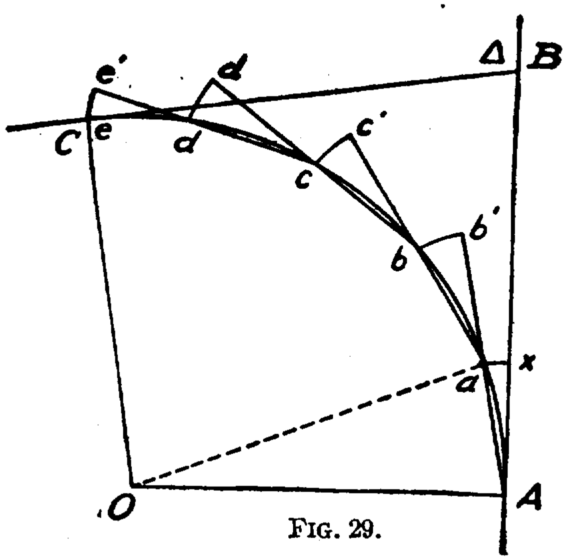

FIG. 29.

Measure or compute this remaining length of the curve and call it x. Establish a tangent to the curve at d, using $ee' = t$. Lay off $df' = x$ and locate the point f by the same method by which a was established from the tangent AB, using $ff' = \frac{x^2}{C'^2}t$. Bf is the direction of the new tangent. If B is not visible, lay off the distance $\frac{x^2}{C'^2}t$ outward from d along Od and a line through the resulting point and f is the new tangent.

TABLE XII.—Table showing tangent distances and offsets therefrom for certain lengths of chord in a curve of 1′ 0″ radius. All measurements are in decimal parts of the radius.

Length of chord...	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Offset............	0.005	0.020	0.045	0.080	0.125	0.180	0.245	0.320	0.405	0.50
Tangent distance..	0.100	0.199	0.2969	0.3912	0.4841	0.5724	0.6557	0.7332	0.8037	0.8660

The foregoing table is hardly necessary for the tangent offsets, which are always equal to square of the chord divided by 2R.

62. **To locate a curve by middle ordinates.**—P. C., P. T., and R being known, assume some short chord, C′, whose ratio to the corresponding arc is practically unity. From sin 1/2 D′=C′/2R, find D′, the angle that this chord subtends for the given radius. Then $\frac{\Delta}{D'}$ = N, the number of such chords in the curve to be laid out.

Lay off from P. C. toward center the distance A*g* (fig. 30), equal to offset *t*, corresponding to C′, taken from Table XII. Through *g* extend the line *ga* parallel to the tangent AB, and with the P. C. as a center strike an arc with a radius C′. The intersection of these two lines is a point in the curve, *a*.

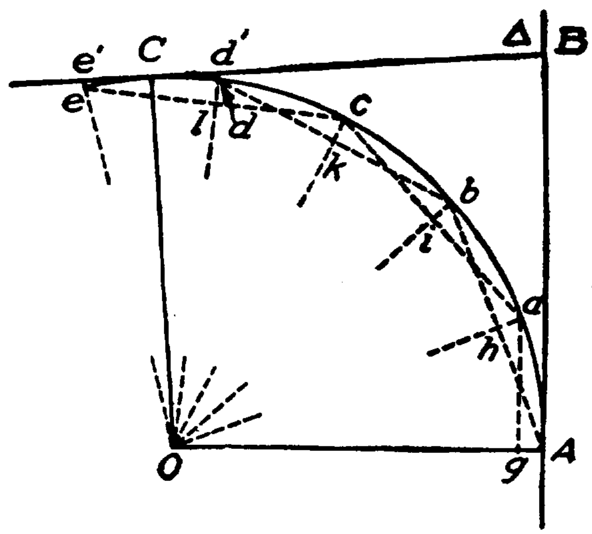

FIG. 30.

From *a* lay off a distance in the direction of the center, *ah*, equal to *t*. Extend the line A*h*, and with *a* as a center strike an arc with C′ as a radius. The intersection of A*h* with this arc is at *b*, another point in the curve.

If N is a whole number, the P. T. will be one of the points found as above. If N is not a whole number, lay off the whole-numbered stations as above until a station, *e*, is located, just beyond the P. T. Measure C*d* and C*e*. From Table XII find the offset corresponding to each of these chords. From *d* and *e* lay off *dd′* and *ee′*, outward from *d* and *e* along the directions *d*O and *e*O. The line *d′e′* should coincide with the new tangent and pass through C. This method is only applicable when O can be seen from all points of the curve.

There is another method of laying off curves without the use of instruments, i. e., by **offsets from the long chord** of the curve, but it is not believed that this method would be of any practical value in the field; and if occasion arises where its use is necessary, the engineer can readily figure out the method for himself.

The foregoing methods will not always locate points on the curve a fixed distance apart, but as rapidity of location is desired rather than careful notes for future record, these methods are suited to military railways.

63. **Laying out curves with a transit.—P. I. accessible.**—Arriving at the P. I., the exterior angle is measured, and knowing either the radius, or the degree of curvature desired, the other is determined as in par. 58. Having located the P. C., the transit is set up at this point and the zeros of the plate and vernier are brought together and clamped in that position. The instrument is then sighted

along the tangent produced and an angle is turned off toward the side to which the curve is going, equal to the chord distance to the next station divided by the distance between stations, and multiplied by one-half the degree of curvature. Thus the P. C is at station 10+40; the degree of curvature is 4° R; the length of stations used is 100 ft. To locate station 11 turn off $\frac{60}{100}\times 2°$, or 1° 12′, to the right and measure 60 ft. along this line. The rear chainman holds the 40-ft. point on the P. C.; the head chainman moves to the right of the tangent until the point of his flag, held at the end of the chain, is bisected by the vertical cross hair. A stake is driven at this point and a nail is driven in the stake and the point is verified by the instrument man and the head chainman. The chainmen move out and thereafter use the full chain. The instrument man thereafter lays off 2°, that is, half the degree of curvature, for each station until the last station in the curve is reached. He then lays off the proper proportional part of the deflection angle, which should be equal to the difference between the sum of all the angles theretofore laid off and half the external angle. The line of sight should then intersect the tangent at the P. T. if the work has been correctly done, and the **length of the curve** should be $100\frac{\Delta}{D}$ ft. If either of these two conditions is not fulfilled on reaching the P. T., some mistake has been made and the work must be corrected. In turning off these angles as above, it is best to make out a table before starting that shows what the vernier should read at each point. This does away with the chance of a cumulative error that exists in turning off a small angle several times.

64. **P. I. inaccessible.**—When the P. I. is inaccessible, it may be necessary to make several changes of direction, as in fig. 31. The point V would be the P. I., but it is inaccessible. The line is run along APQB, QB being the desired direction of the new tangent. The external angle is then equal to the sum of the deflection angles at P and at Q. In the triangle QPV, all the angles and the side PQ are known. Solve the triangle for QV and PV. Find the tangent distance VB and VA as in par. 58, and lay off from Q, QB equal to VB minus VQ; and from P, a distance equal to VA minus VP. The points B and A thus located are the P. T. and P. C., respectively. The curve is then laid out as heretofore described.

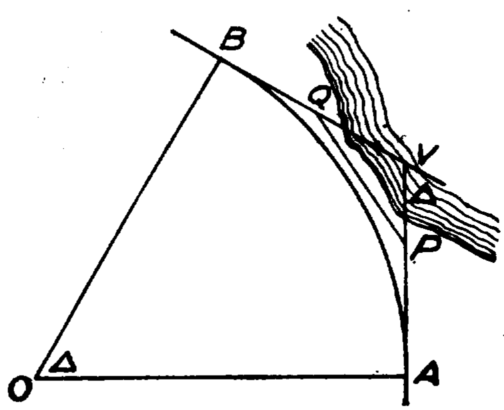

FIG. 31.

65. **A curve requiring more than one setting of the instrument.**—As errors will creep into the location of a curve if very long lines of sight are used in laying out the curve, it is customary not to lay out more than from four to six stations from one point; therefore, on curves longer than this, two or more settings of the instrument will be necessary. This is also the case when the line of sight is interfered with by some obstacle. Having located the curve as far as Q, in fig. 32, from the P. C., it is decided to use a new setting of the instrument. The instrument is moved to Q and set up over this station. The zeros having been brought together, a backsight is taken on the P. C., the telescope is plunged, and an angle is turned off to the inside of the curve equal to $\frac{D}{2}$ multiplied by the curve distance to Q, in feet, and divided by 100. This is equal to the angle VAQ. The instrument should now read the same angle that it did to locate Q, and the line of sight is tangent to the curve at this point. From Q the curve is continued in the same manner that it was from the P. C.

To be general; when the instrument is set up on any forward station of a curve, backsight to any previous station with the plates set at the originally computed deflection angle for the station sighted at. Plunge the telescope and set the plate at the angle of deflection originally computed for any forward station and the line of sight will point to that station.

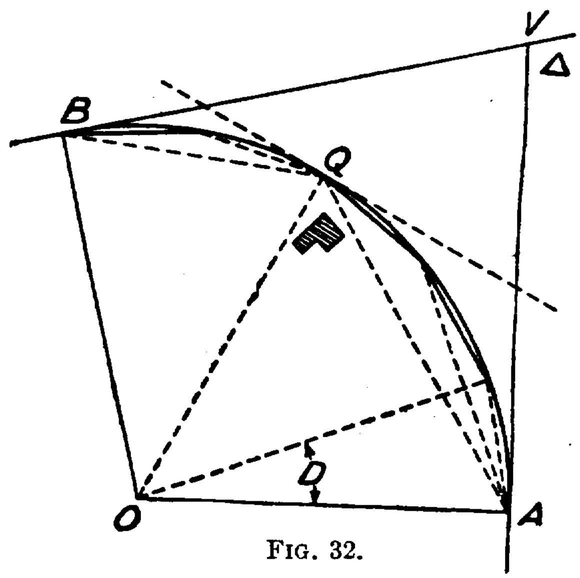

FIG. 32.

In locating curves on a line of railroad, many problems will come up for solution too numerous for description here. A knowledge of trigonometry and the use of formulæ in Table XVII will solve any problem that may arise.

66. Reverse curves.—A reverse curve should not be located in a line of railway unless it is impossible to avoid using it, and two curves, curving in opposite directions, should not be nearer to each other than at least the length of the longest train that it is expected to run over the line.

67. Easement or transition curves.—A good rule for the length of such a curve is that it shall be equal to the run-off of the superelevation of the outer rail. The transition spiral is too complicated for a full description, but its application is fairly simple. In fig. 33, ABC is the circular curve for which a transition curve, EGIB′, leading into a parallel circular curve A′B′C′, is to be substituted. The form of the **cubic parabola** is used, and is applicable wherever ED is equal to or

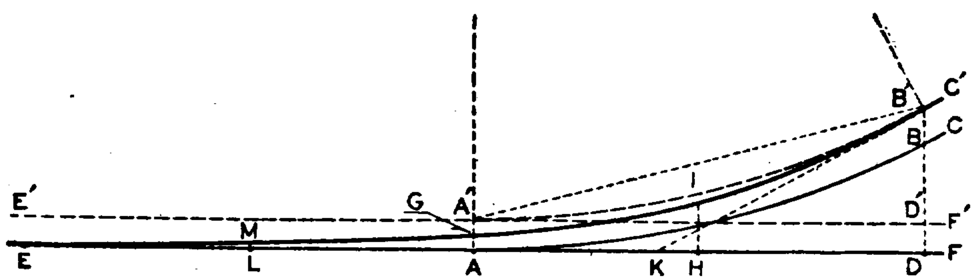

FIG. 33.—TRANSITION CURVE.

less than 0.38 R, or to be concrete up to an 11° curve, with 5-ins. elevation to the outer rail run out in 200 feet. On curves sharper than 11° a rough easement curve can be put in by applying similar methods. The curve will not be a real cubic parabola, but will be better than the sudden circular curve.

Having decided upon the elevation of the outer rail for the main curve, the length of the easement curve ED may be assumed as from 400 to 600 times the proposed elevation, and the points E and D located equidistant from A. The corresponding offset DB′ is then $(ED)^2$, divided by 6 times the radius of the curve ABC, and can be laid off perpendicular to ED.

The relation between DB′ and the perpendicular offset, HI, to any point, I, in the transition curve is then:

$$HI : DB' :: \overline{EH^3} : \overline{ED^3}; \text{ or } HI = DB'\frac{\overline{EH^3}}{\overline{ED^3}} = \overline{ED}.$$

Therefore AG, at the original PC is $\frac{1}{8}$ DB; while at the quarter points, L and H, the offsets are $\frac{1}{64}$ DB′ and $\frac{27}{64}$ DB′, respectively. A tangent to the curve at B′ cuts the line ED at a point K, such that KD = $\frac{1}{3}$ED. (The line KD in fig. 33 is distorted, because it was necessary to make ED much greater than 0.38 R to give a clear diagram.) The main curve can be continued from B′, by back-sighting either on A′ or K. From fig. 33 AA′ = $\frac{1}{4}$ DB′ = $\frac{1}{3}$D′B′, whence the deflection angle B′A′D′ can be determined, since R ver. sin 2 B′A′D′ = D′B′.

68. **Corrections for curves of over 10°.**—It will be seen that in the foregoing curve work there is a slight error, due to the difference in length between an arc and the 100-ft. chord used in chaining. This difference is inappreciable for curves up to 10°. For curves sharper than this, there is a measurable correction to be applied, especially when subchords are used. In locating a very sharp curve, points must be located less than 100 ft. apart to properly outline the curve. In fig. 34 it is desired to use n subchords, and to find the length, C′, of the subchord AB. $\frac{D}{n}$ is the angle AOB, subtended by subchord C′.

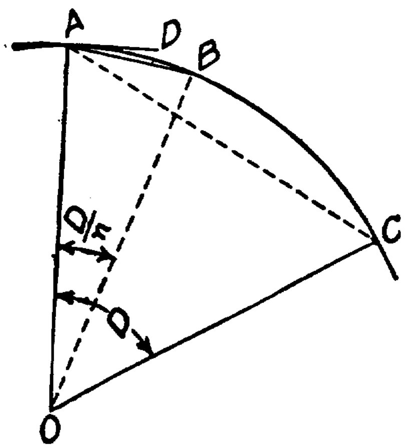

FIG. 34.

D = degree of curvature = AOC.

$$\text{Then, } C' = 2R \sin\frac{D}{2n};$$

$$\text{then, as } 2R = \frac{100}{\sin\frac{D}{2}},$$

$$C' = \frac{100 \sin\frac{D}{2n}}{\sin\frac{D}{2}},$$

$$\text{and } \sin\frac{D}{2n} = \frac{C'}{100}\sin\frac{D}{2}.$$

Example.—Required to lay off a 36° curve with short chords so that a 100-ft. chord will subtend 36° at the center. What is the actual chord length to be used, when we wish to use three short chords?

$$\frac{D}{2n} = \frac{36^\circ}{6} = 6^\circ = BAD.$$

$$\frac{D}{2} = 18^\circ\ 00'.$$

$$\therefore C' = 100 \times \frac{\sin 6^\circ}{\sin 18^\circ} = \frac{10.45}{.309} = 33.81 \text{ ft.}$$

The chord 33.81′ is used and 6° is turned off for each such distance.

69. **Increase in gage.**—In laying track on tangents the rails are laid with the distance from the inside of one rail to the inside of the other rail the exact gage of the track. On curves, however, it has been found better to slightly widen the gage.

This is done on account of the rigid wheel base and the consequent wear of the wheels and rails. For curves less than 3° there is no increase in the gage of the track. For curves sharper than this, the increase, according to good American practice, is shown in Table XIII. This table also shows the **distance of the guard rail** from the inner main rail. The increase in gage on a curve is dependent upon the length of the rigid wheel base and the radius of curvature. A general case can be found from the formula

$$I=\frac{3L^2}{2R} \text{ (approximately)},$$

in which L equals the length of the rigid wheel base in feet, R is the radius of the curve in feet, and I is the increase in gage in inches. This is an English rule and agrees with U. S. practice. I should never exceed about one-third of the tread. Note in Table XIII that the guard rail is a *constant* distance from the *outer* rail.

TABLE XIII.—**Increase in gage** of track on **curves.**

Degree of curve.	Increase over standard gage.	Gage of track.	Distance of guard rail from main rail.
Less than 3°	0 in	4 ft. 8½ ins	1¾ ins.
3°	1/16 in	4 ft. 8 9/16 ins	1 11/16 ins.
5°	⅛ in	4 ft. 8⅝ ins	1⅞ ins.
7°	¼ in	4 ft. 8¾ ins	2 ins.
9°	⅜ in	4 ft. 8⅞ ins	2⅛ ins.
11°	½ in	4 ft. 9 ins	2¼ ins.
13°	⅝ in	4 ft. 9⅛ ins	2⅜ ins.
15°	¾ in	4 ft. 9¼ ins	2½ ins.
17°	⅞ in	4 ft. 9⅜ ins	2⅝ ins.
19°	1 in	4 ft. 9½ ins	2¾ ins.
21°	1⅛ ins	4 ft. 9⅝ ins	2⅞ ins.

This table is for a first-class road. The rigid wheel base of the locomotives is about 12 to 15 ft.

70. **Elevation of the outer rail.**—The elevation of the outer rail on a curve is dependent upon the radius of the curve, the speed of the train, and the gage of the track, and can be found from the following formula:

$$E=\frac{gV^2}{15R},$$

in which E is super-elevation in feet,
g is gage in feet,
R is radius in feet,
V is velocity in miles per hour.

71. In making this **correction for curvature** the inner rail may be carried along at grade and the entire elevation may be given to the outside rail, or the center line may be carried at grade and the outer rail laid one-half the elevation above the center line and the inner rail one-half the elevation below the center line. The former is considered the better practice. Whichever method is followed, the rails at the P. C. should have the full difference of elevation, and the difference of elevation is run out on the tangent at the rate of about 0.1 ft. in 60 ft. On a standard-gage military road the speed would doubtless be low, and a good rule for elevation for any curve would be ¾ in. for each degree of curvature, and the maximum elevation for any curve should not exceed 5 ins. Sharp curves and high speed do not go

together. On such curves the speed must be reduced, and the allowable speed may be found from the above formula by solving for V. A slow sign should be posted at both ends of such a curve.

72. **Lead of inside rail.**—Due to the shorter radius of the inner rail, its joints will run ahead of those of the outer rail and certain corrections must be made to keep the joints approximately square. This difference is $L - \frac{R+\frac{1}{2}g}{R-\frac{1}{2}g}L$, when R is the radius, g the gage, and L the length of rail. By using the short length rails on the curves, the joints can be kept approximately square without cutting rails. (See Table V as to specifications for rail lengths.)

73. **To find the degree of curvature.**—The middle ordinate of a 61.8-foot chord, measured in inches, gives the degree of curvature. This is only correct when the rails are properly curved, and on roughly lined curves will not give accurate results. The average of several trials is more accurate than a single measurement. **Another method** of determining the degree of curvature is shown in fig. 35, using the gage of the track, a measurement that is usually accurate, as a middle ordinate. Sight from C to A, making AC tangent to the inner rail at B. Measure AC and DB. CB should equal BA, and the point A should be relocated if measurements do not agree.

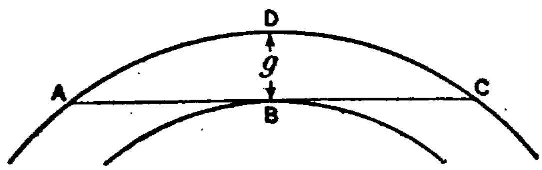

FIG. 35.

Then $R = \frac{BA^2}{2g}$

Then the degree of the curve equals $\frac{5730}{R}$.

74. **Vertical curves.**—On a line with grades as great as 1% and 2%, vertical curves will be necessary where two sharp grades come together. The curve is usually in the form of a parabola. The American Railway Engineering Association recommends that for the same change of grade the length of vertical curve in a sag should be twice what it would be for the same change on a summit, while other engineers would make them of equal length.

In fig. 36 AB is the upgrade and BC the downgrade. The stations indicated are 100-ft. stations. It is desired to run in a vertical curve on this hill and avoid the sharp change at B. Decide on the desired length of the vertical curve, and on the

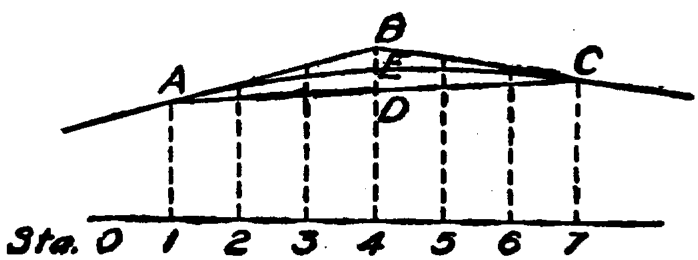

FIG. 36.—VERTICAL CURVE.

profile draw the chord AC corresponding to this length. Half the difference between the elevation of B and D is approximately the middle ordinate of the curve, and locates the elevation of the curve at the point E. Then let M be the *correction* in elevation at the point B.

$$BE = M = \frac{1}{2}\left(\frac{\text{elev. A} + \text{elev. C}}{2} - \text{elev. B}\right).$$

The correction for any other point of the vertical curve is proportional to the square of its distance from the nearest end of the curve divided by the square of the half length AB. The correction is negative when the curve is concave downward, and is positive when the curve is concave upward.

Vertical curves vary in length according to the change in grades. The A. R. E. A. rule is that the length of the vertical curve, AC, equals the change of adjacent grades (in per cents) multiplied by 1,000 ft. for summits or 2,000 ft. for sags. These lengths can safely be reduced to 250 and 500 ft., respectively. The resulting curve should extend an equal distance on each side of the apex. Improvements in couplers and brakes are decreasing the necessity of long vertical curves.

Example.—A +2% grade joins a −1.5% grade. How long should the vertical curve be? (2+1.5) 250=875 ft.; 437½ on each slope.

75. **Drains and culverts.**—The engineer should examine every depression crossed in the survey, and will decide whether or not water will accumulate behind the railroad bank if no culvert is put in. If there is a drainage area of any extent on the uphill side, a culvert or drain of some sort will be put through the embankment at this point to carry off the water. A blind drain will sometimes answer, but it is better to put in a box drain or leave an opening in the embankment and put in a small bridge. These drains should be perpendicular to the track. The area of the opening in square feet given by Myer's formula is:

$$A = C\sqrt{\text{drainage area in acres.}} \quad C = \begin{cases} 1, \text{ in flat country.} \\ 1\frac{1}{2}, \text{ in hilly country.} \\ 4, \text{ in rocky, mountainous country.} \end{cases}$$

76. **Tunnels.**—In a field line a tunnel is practically an impossibility on account of the difficulties of construction and the time necessary to build one. If necessary a temporary timber-lined tunnel may be constructed by an application of methods described in Part V, Field Fortification, under Mining.

CONSTRUCTION.

77. **The roadbed** is the support prepared for the track. It generally consists of the **foundation** and the **ballast.** The latter should be a material the consistency of which is not affected by water, and especially which does not become slippery when wet. Sand will do if nothing else can be had; gravel is better, and broken stone is the best of all. Cinders, shells, burnt clay, and other materials are also used. The surface of the foundation on which the ballast rests is called the **subgrade.**

Unless the natural ground is very unfavorable, it will not be necessary to use a separate material for ballast and the subgrade really disappears. Even then, the earth between and immediately under the ties which is dug into in surfacing the track is called ballast. Such roads, usually called **mud roads,** will be the rule in military practice.

78. The cross section of the roadbed must be decided upon before the level party starts on its work, in order that they may know the dimensions of the roadbed for which the stakes are to be set. Figs. 41–47 show the dimensions of standard-gage roads. For any other gage the slopes will be the same, but the shoulders outside of the ties will be slightly less. The difference will therefore be the difference in the gage of the tracks, plus twice the amount that the shoulder can be reduced in width. The dimensions of the roadbed of a 2 ft. 6 in. track would be, approximately, 11 ft. from shoulder to shoulder on a fill and 10 ft. from shoulder to shoulder in a cut. The dimensions for a track of 3-ft. gage will be about 12 ft. from shoulder to shoulder on an embankment and about 11 ft. in a cut. In excavations, plenty of depth should be allowed for **ditches** in order to insure a dry roadbed.

Wherever the grades permit, the track will be laid directly on the surface of the ground, and the necessary leveling up can be done after the track has been laid. It must be continually kept in mind that the first object desired is to get some sort of railway connection established, and that the betterments to the line in slight changes of grade, etc., can come afterward and not interfere with traffic.

79. **The track** consists of the **ties**, the **rails**, and the attachments of the latter to the former and to each other.

Ties for military roads will be made of the most accessible wood, and should be 8 ft. long, 6 to 7 ins. thick, and 8 to 10 ins. face, top and bottom, if hewed, and 9 ins. if sawed. They should be spaced 24 ins. c. to c., as a rule, but if the ties are broad it may be necessary to space them wider, as clear room between of 12 ins. is needed for tamping. It is usual to allot a certain number of ties (14 to 18) to a 30-ft. rail, and space them equal clear distances rather than equal center distances.

Rails are 30 ft. in standard length. The size of rails is reckoned by the weight per yard in lbs., and varies from 12 to 110 lbs., the former used for industrial and construction roads and the latter on a few of the highest class trunk lines. Rails for military roads will probably run from 60 to 80 lbs. The name of the mill and the weight per yard are rolled in raised letters on the web of each rail at short intervals.

80. **Rail joints.**—A rail joint consists of a pair of **fishplates,** or **angle bars,** and from four to six bolts. The length of angle bar used to-day varies from 17 to 48 ins. The bolts should alternate, one head inside and the next head outside of the track. Fig. 37 shows different classes of rail joints and tie arrangements.

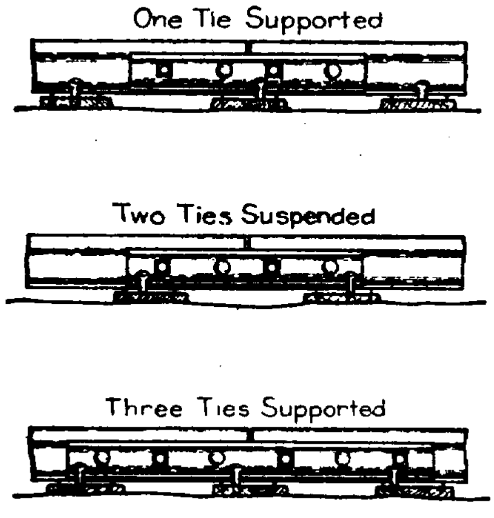

FIG. 37.—TYPES OF RAIL JOINTS AND TIE ARRANGEMENT.

Joints are either **suspended** or **supported.** The former are believed to be the most satisfactory. For size and weights of various accessories, see Tables II to VIII.

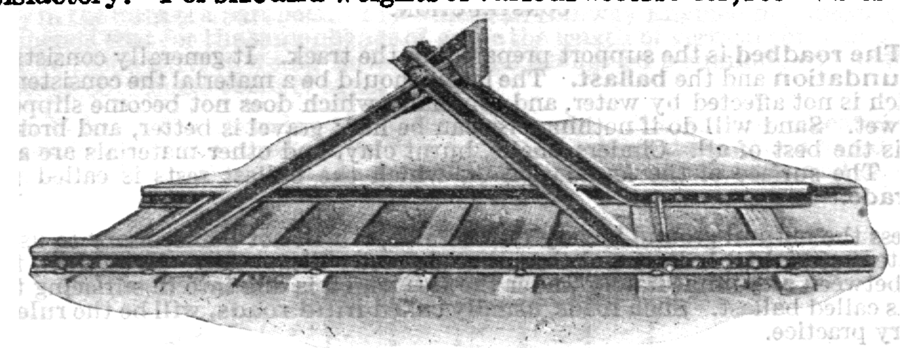

FIG. 38.

81. **Buffers.**—A buffer, or bumping post, is an arrangement placed at the end of a spur track to prevent the cars from running off the end of the track. A commercial form of the same is shown in fig. 38.

A heavy timber chained across the track answers very well for a bumping post. One of the simplest and best means of ending a spur track is to dump a **pile of cinders** across the end of the track for about half a car length from the end, about 3 ft. thick.

82. **Tie plates.**—On curves and bridges, tie plates can be used advantageously. These plates are usually of steel and prevent the rail from cutting into the tie (see fig. 39).

83. **Spikes.**—The commonest form of railway spike is shown in fig. 40. The weights of these for various sizes are shown in Table VII. The cutting edge of the spike is across the grain in crossties; if the rails are to be spiked to stringers, as occasionally on a bridge, the spikes should be "reversed" by a smith.

84. **Organization of working parties.**—The actual organization of the working parties will depend upon the manner in which it is planned to move the earth. However, there are a few cardinal principles which will apply in every case.

The work must be **laid out** far enough in advance so that no working party, either teams or men, shall be idle through lack of orders.

The men and animals must be housed and fed as well as conditions will permit. For this purpose, a quartermaster should be detailed, with a sufficient number of assistants to thoroughly handle these two important duties.

FIG. 39.—TIE PLATE.

85. The **quartermaster**, or one of his assistants, will have charge of all tools and supplies. He will be responsible for getting them to the front when wanted, and for distribution before working hours and collection afterwards. He is responsible for all camps, camp equipage, and transportation. He will be in charge of the messing and act as paymaster.

86. The **health of the men** should be looked after by a detail from the medical department, whose business it is to look after the sanitation of the camps, the proper policing of the water supply, and the general health of the men. The **health of the animals** is also important, and a proper number of veterinarians should be employed to take care of them.

87. The camps will be so located that the least possible time will be lost in getting the entire force onto the work, and the camp will be moved from time to time to fill this requirement. If necessary for the safety of the camp and the working parties, **a proper guard** will be detailed, whose commander will report to the engineer in charge of the party or parties that are to be protected. The **guard commander** of the camp will be responsible to the engineer in charge for the security and safety of the camp and working parties. He will perform his duties in the manner prescribed for the outpost commander in the Field Service Regulations, and will keep the engineer in charge fully informed as to the precautions that he has taken, and will give him timely warning of an enemy's approach.

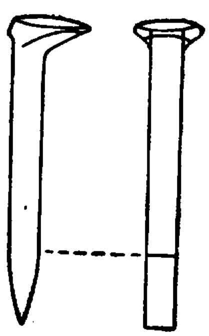

FIG. 40.—RAILROAD SPIKE.

88. **Clearing and grubbing.**—The first party sent out clears the right of way of all trees, brush, etc., and is followed by a party to grub out stumps that lie in the actual roadbed wherever the fill is not over 2 ft. Stumps up to 12 ins. in diameter can be pulled by means of a **stump puller,** which requires the use of one team and two or three men. For stumps larger than 12 ins. in diameter it is probable that dynamite will be used. To get a stump out by this means a trench is dug around the stump from 2 to 4 ft. wide and of sufficient depth to uncover the main body of the stump. A hole is bored under the stump with a 2-in. auger, and one or two ½-lb. sticks of dynamite are pushed into the hole and exploded. This small charge springs a large opening under the stump, into which the necessary amount of dynamite or powder is placed and exploded.

89. **Earth work.**—For details as to earth work, see Part III—Roads.