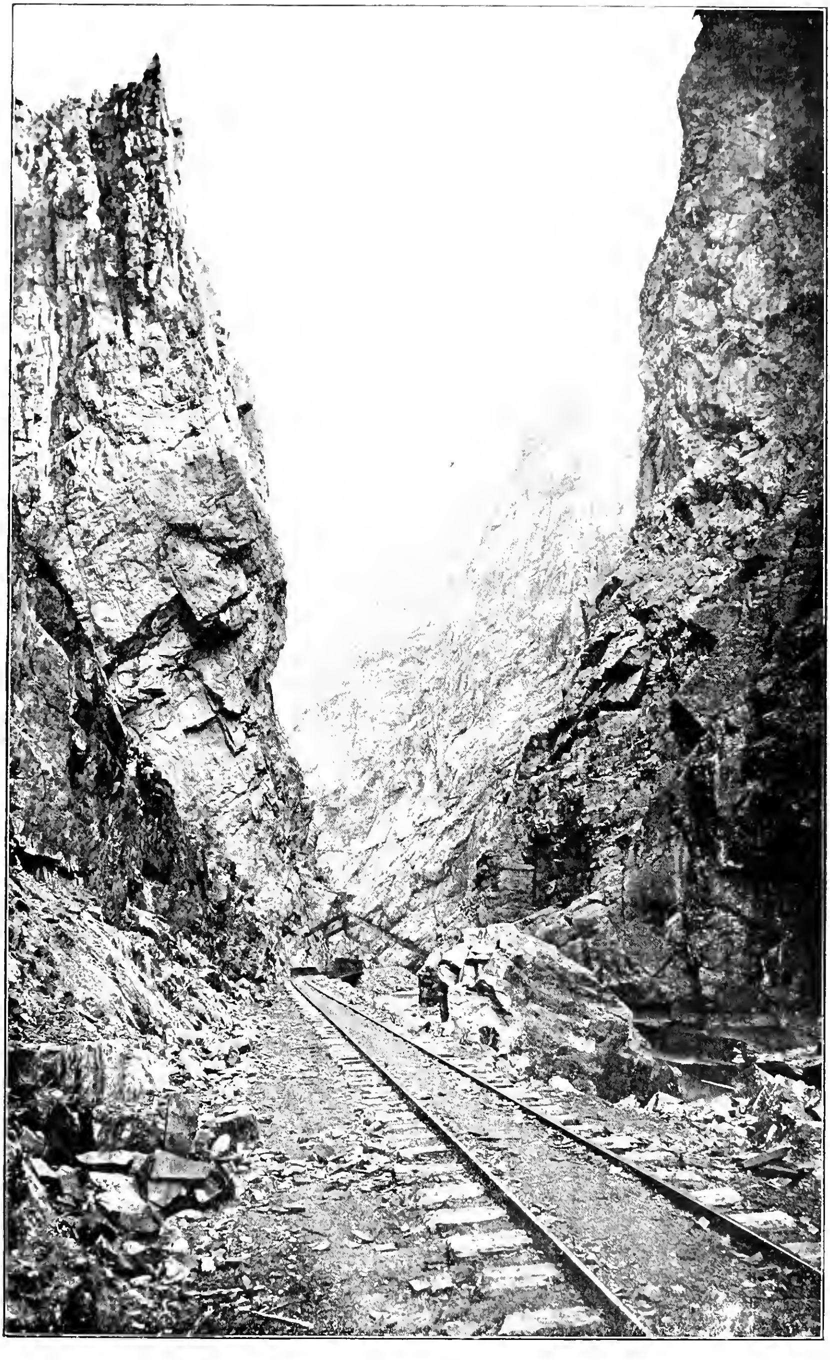
PART IV.

SOME FEATURES OF RAILROAD ENGINEERING.

CHAPTER XXI.

254. **Introductory.**—The first step toward the construction of a railroad is the location of the line, which requires as an initiative a careful ocular examination of the general vicinity of the proposed road, supplemented by simple and approximate instrumental work rapidly performed. Following this reconnaissance, as it is called, more complete surveys and examinations are made both in the field and on the maps plotted from the data of the field-work. The prosecution of this series of operations produces the final location, together with the accumulation of such maps, profiles, and other data as may be required in the construction of the road-bed, bridges, and other structures constituting the complete railroad line with its ballast and track in place ready for traffic.

The ultimate purpose of any railroad line is the transportation of passengers and freight under conditions, including those of a physical nature connected with the road as well as the rates received, leading to profitable returns. Competition or other circumstances attending the traffic of a given road will fix the maximum rates to be charged for transportation. It is the business, first, of the civil engineer so to locate and design the road and, second, of the manager so to conduct the transportation as to make the margin of profits the greatest possible. It will be the purpose of this lecture to consider in a general way only



The Royal Gorge.

some of the features of a railroad and its operation which are related directly to civil engineering.

255. Train Resistances.—It is a fact confirmed by constant daily experience that, however nicely the machine impelling the railroad train or the tracks supporting the cars may be built, considerable frictional and other resistance is offered to the movement of the train when the latter passes over a perfectly level and straight track.

A considerable portion of the cost of transportation is expended in overcoming this resistance. When the line fails to be either level or straight other resistances of magnitude are developed; they are called the resistances of grades and curves: and it is the business of the civil engineer so to design the railroad as to reduce these two classes of resistance to an absolute minimum, in view of certain other conditions which must be concurrently maintained.

256. Grades.—The grade of a railroad is expressed usually in this country by the number of feet through which 100 feet of length of line rises or falls, or by some expression equivalent to that. If, for instance, the line rises 1.5 or 2 feet in 100, it is said to have an ascending grade of 1.5 or 2 per cent. Or if the line falls the same amount in the same length, it is said to have a descending grade of 1.5 or 2 per cent. It is evident that a grade which descends in one direction would be an ascending grade for trains moving in the opposite direction, so that grades favoring traffic in one direction oppose it in the other. Hence, other things being equal, that road is the most advantageous for the movement of trains which has the least grade. The grades of railroads seldom exceed 2 or 2.5 per cent, although, as will presently be shown, there are some striking exceptions to that general observation. The actual angles of inclination of railroad tracks from a horizontal line are therefore as angles very small, but their disadvantages for traffic increase rapidly.

A simple principle in mechanics shows that if the railroad train with a weight W moves up a 2 per cent grade, one component of the train weight acts directly against the tractive force of the locomotive or other motive power. If a is the angle of inclination of the track to a horizontal line, this opposing component will have the value $W \sin a$. When angles are small their sines are essentially equal to their tangents. Hence, in this case, $\sin a$ would have the value .02 or 1/50 of the train weight. If the weight of the train were 500 tons, which is a rather light train for the present time, this opposing force would be 10 tons, or 20,000 pounds, which, as we shall see later on, is more than one half of the total tractive force of any but the heaviest locomotives built at the present day. This simple instance shows the advantage of keeping railroad grades down to the lowest practicable values.

One of the most economical freight-carrying roads in the United States is the Lake Shore and Michigan Southern of the New York Central system, running from Buffalo to Chicago. Its maximum grade is 0.4 of 1 per cent. The maximum grade of the N. Y. C. & H. R. R. R. is 0.75 of 1 per cent between New York City and Albany and between Albany and Buffalo, 1.74 per cent at Albany, 1.12 per cent at Schenectady, and 1 per cent at Batavia. Pushers or assistant locomotives are used for heavy trains at the three latter points. The maximum grade of the Pennsylvania R. R. on the famous Horseshoe Curve between Altoona and Cresson is 1.8 per cent. It is advantageous, whereever practicable, to concentrate heavy grades within a short distance, as in the case of the New York Central at Albany, and use auxiliary engines, called pushers or assistants. Some of the heaviest grades used in this country are found on the trans-continental lines where they pass the summits of the Rocky Mountains or the Sierras. In one portion of its line over a stretch of 25.4 miles the Southern Pacific R. R. rises 2674 feet with a maximum grade of 2.2 per cent; also approaching the Tehacipi Pass in California the maximum grade is about 2.4 per cent. At the Marshall Pass on the Denver & Rio Grande R. R. there is a rise of 3675 feet in 25 miles with a maximum grade of 4 per cent. The Central Pacific R. R. (now a part of the Southern Pacific system) rises 992 feet in 13 miles with a maximum grade of 2 per cent. The Northern Pacific R. R. rises at one place 1668 feet in an air-line distance of 13 miles with a maximum grade of 2.2 per cent. Probably the heaviest grade in the world on an ordinary steam railroad is that of the Calumet Mine branch of the Denver & Rio Grande R. R., which makes an elevation of 2700 feet in 7 miles on an 8 per cent grade and with 25° curves as maximum curvature. These instances are sufficient to illustrate maximum railroad grades found in the United States.

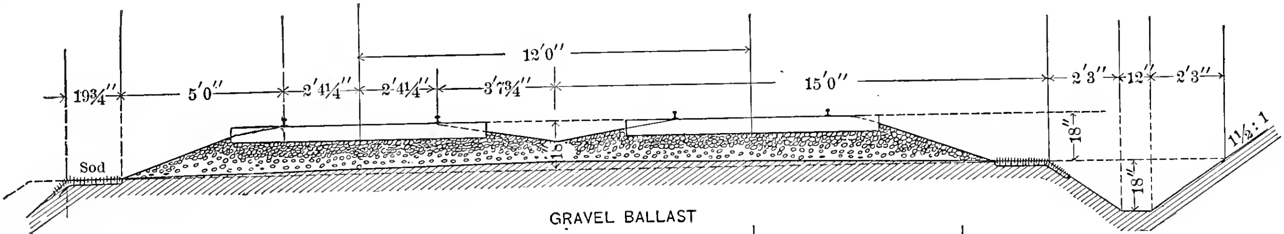
257. Curves.—Civil engineers in different parts of the world have rather peculiar classifications of curves. In this country the railroad curve is indicated by the number of degrees in it which subtend a chord 100 feet in length. Evidently the smaller the radius or the sharper the curvature the greater will be the number of degrees between the radii drawn from the centre of a circle to the extremities of a 100-feet chord. American civil engineers use this system for the reason that the usual tape or chain used in railroad surveying is 100 feet long. A very simple and elementary trigonometric analysis shows that under this system the radius of any curve will be equal to 50 divided by the sine of one half of the angle between the two radii drawn to the extremities of the 100-feet chord. In other words, it is equal to 50 divided by the sine of one half the degree of curvature. The application of this simple formula will give the following tabular values of the radii for the curves indicated:

Curve.	Radius in Feet.
1°	5729.65
2°	2864.93
3°	1910.08
4°	1432.69
5°	1146.28
6°	955.36
7°	819.02
8°	716.78
9°	637.27
10°	573.69
12°	478.74
15°	383.06
20°	287.91

258. Resistance of Curves and Compensation in Grades.—Inasmuch as the resistance offered to hauling the train around a curve increases quite rapidly as the radius of curvature decreases, it is obvious that in constructing a railroad the degree of each curve should be kept as low as practicable, and that there should be no more curves than necessary. While no definite rule can be given as to such matters, curves as sharp as 10° (573.69 feet radius) should be avoided wherever practicable. It is not advisable to run trains at the highest attainable speeds around such curves, nor is it done. Inasmuch as curve resistance has considerable magnitude, as well as the resistance of grades, it is natural that wherever curves occur grades should be less than would be permissible on straight lines or, as they are called, tangents. If a maximum gradient is prescribed in the construction of a railroad, that gradient will determine the maximum weight of train which can be hauled on the straight portions or tangents of the road. If one of these grades should occur on a curve, a less weight of train could be handled by the same engine than on a tangent. Hence it is customary to reduce grades by a small amount for each degree of curvature of a curve. This operation of modifying the grades on curves so as to enable a locomotive to haul the same train around them as up the maximum grade on a tangent is called compensating the curves for grade. There is no regular rule prescribed for this purpose, because the combination may necessarily vary between rather wide limits in view of speed, condition of track, and other influencing elements. The compensation, however, has perhaps frequently been taken as lying between .03 and .05 per cent of grade for each degree of curvature. In other words, for a 5° curve the grade would be .15 to .25 per cent less than on a tangent. This compensation for grades is carefully considered in each case by civil engineers in view of experience and such data as special investigations and general railroad operation have shown to be expedient.

259. Transition Curves.—High speeds for which modern railroads are constructed have made it necessary not only to protect road-beds, but also to make the passage from tangents to curves as easy and smooth as possible. This is accomplished by introducing between the curve and the tangent at each end what is called a "transition" curve. This is a compound curve, i.e., a curve with varying radius. At the point where the tangent or

FIG. 1.



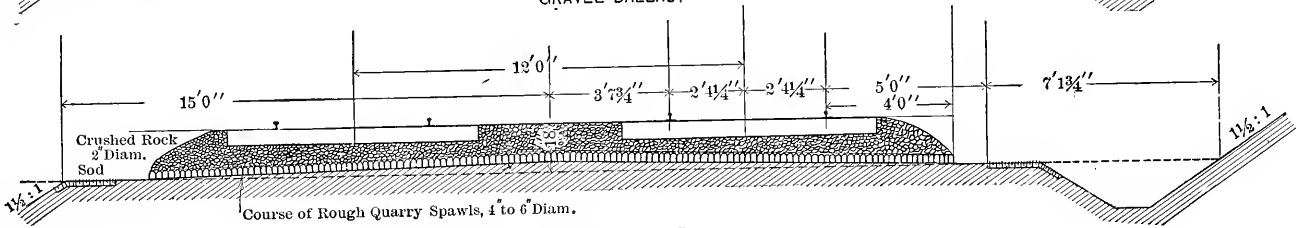


FIG. 2.

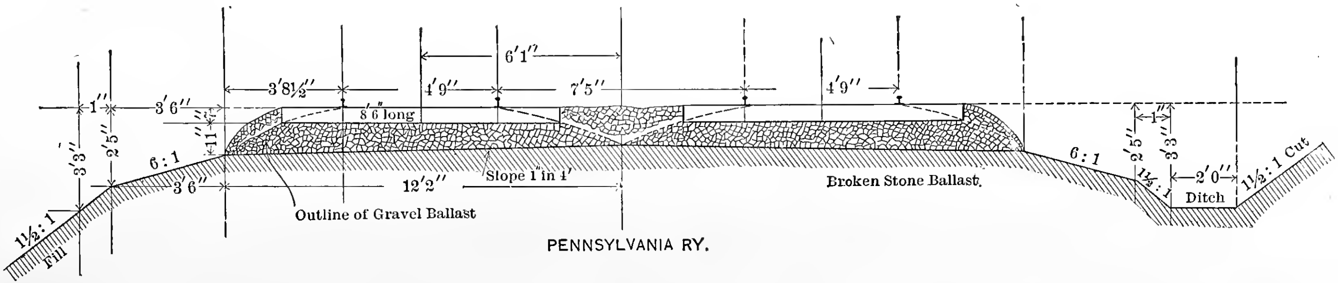


FIG. 3.

straight line ceases the radius of the transition curve is infinitely great, and it is gradually reduced to the radius of the actual curve at the point where it meets the latter. By means of such gradual change of curvature the trucks of a rapidly moving train do not suddenly pass from the tangent to the curve proper, but they pass gradually from motion in a straight line to the sharpest curvature over the transition curve. The rate of transition is fixed by the character of the curves, which have been subjected to careful analysis by civil engineers, and they can be found fully discussed in standard works on railroad location.

260. Road-bed, including Ties.—Not only the high rates of speed of modern railroad trains but the great weights of locomotives and cars have demanded a remarkable degree of perfection in the construction of the road-bed and in the manufacture of rails. The favorite ballast at the present time for the best types of road-beds is generally broken stone, although gravel is used. The first requisites are a solid foundation and perfect drainage whether in cuts or fills. Figs. 1, 2, 3, and 4 show two or three types of road-bed used by the New York Central and Hudson River R. R., the Pennsylvania R. R., and a special type adopted by the B. & O. for the belt-line tunnel at Baltimore. These sections show all main dimensions and the provision made for drainage. The general depth of ballast is about 18 inches, including the drainage layer at the bottom. The total width of road-bed for a double-track line varies frequently between 24 and 25 feet, while the width of a single-track line may be found between 13 and 14 feet. In the cross-sections shown the requirements for drainage

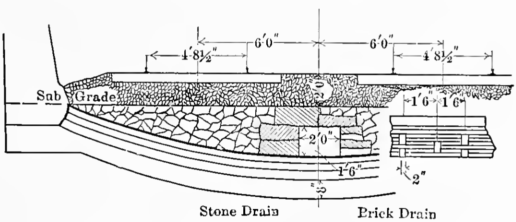


FIG. 4.—Baltimore Belt-line Tunnel, B. & O. Ry.

are found to be admirably met. Timber ties are almost invariably used at the present time in this country, although some experimental steel ties have been laid at various points. Fig. 5 shows the steel tie adopted for experiment on the N. Y. C. & H. R. R. R. within the city limits of New York. The time will undoubtedly come when some substitute for timber must be found, but the

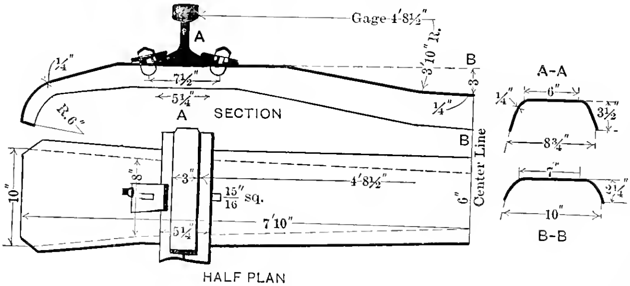


FIG. 5.

additional cost of steel ties at the present time does not indicate their early adoption.

261. Mountain Locations of Railroad Lines.—The skill of the civil engineer is sometimes seve ely taxed in making mountain locations of railroads. Probably no more skilful engineering

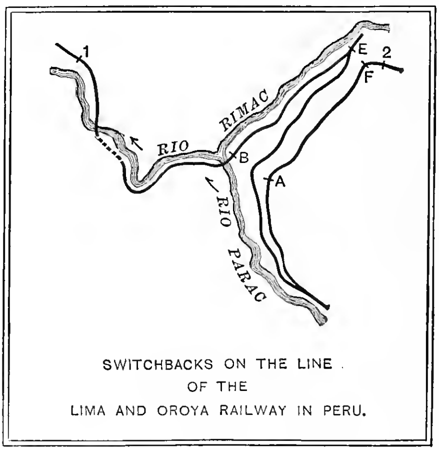
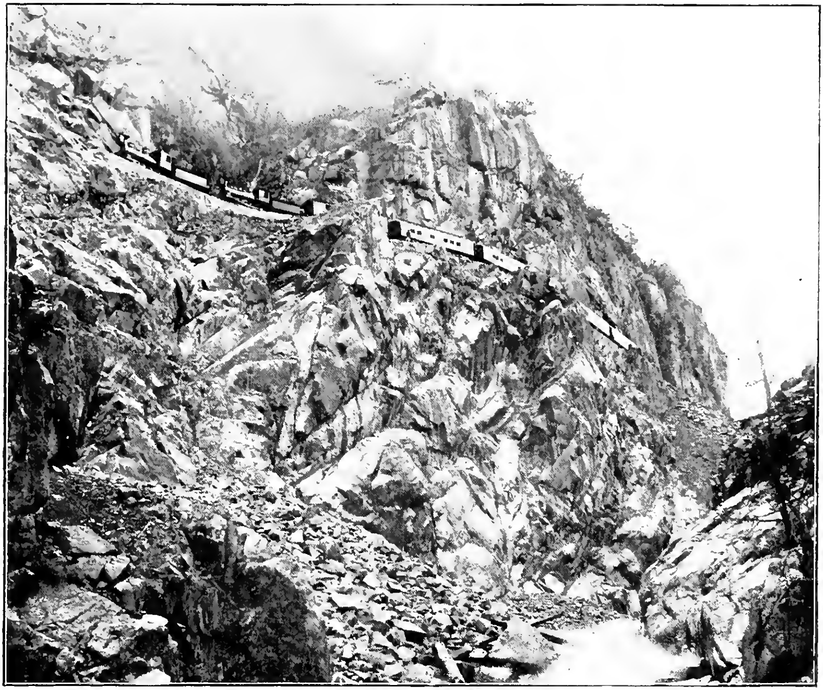


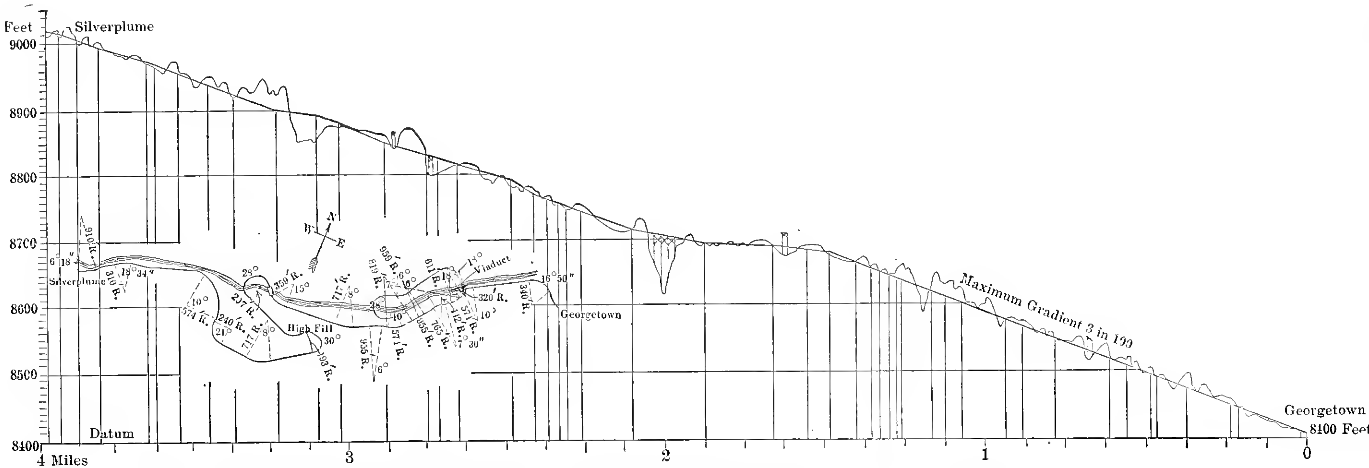
FIG. 6.

work of this kind has ever been done than in the crossings of the Rocky Mountains and the Sierras in this country by trans-continental railroad lines, although more striking examples of railroad location for short distances may perhaps be found in Europe or other countries. The main problem in such cases is the making of distance in order to attain a desired elevation without exceeding maximum grades, such as those which have already been given. Most interesting engineering expedients must sometimes be resorted to. One of the oldest of these is the switchback plan shown in Fig. 6. This is probably the simplest procedure in order to make distance in attaining elevation. The line is



Cañon of the Rio Las Animas, near Rockwood.

run up the side of a mountain at its maximum grade as far in one direction as it may be desirable to go. It then runs back on itself a short distance before being diverted so as to pass up another grade in the reverse direction. This zigzagging of alignment may obviously be made to attain any desired elevation and so overcome the summit of a mountain range. The old switchback coal road near Mauch Chunk, Pa., is one of the oldest and more famous instances of the method, which has many times been employed in other locations.



PLAN AND PROFILE OF THE BRIDGE SPIRAL ON GEORGETOWN BRANCH OF THE UNION PACIFIC RAILWAY IN COLORADO.

FIG. 7.

A more striking method, perhaps, is that of loops by which the direction of a line or motion of a train on it is continuous. Distance is made by a judicious use of the topography of the locality so as to run the line as far up the side of the valley as practicable and then turn as much as a semicircle or more, sometimes over a bridge structure and sometimes in tunnel, so as to give further elevation by running either on the opposite side of the valley or on the same. A succession of loops or other curves suitably located will give the distance desired in order to reach the summit.

262. The Georgetown Loop.—Fig. 7 shows one of these spiral or loop locations on the Georgetown branch of the Union Pacific Railroad in Colorado. It is a well-known and prominent instance of railroad location of this kind. On the higher portion of this loop system included in the figure there is a viaduct on a curve which crosses the line 75 feet above the rail below it and 90 feet above the water. This location is a specimen of excellent railroad engineering. The length of line shown in the figure, including the spiral, is 8½ miles, and it cost $265,000 per mile exclusive of the bridges.

263. Tunnel-loop Location, Rhætian Railways, Switzerland.—In Figs. 8 and 9 are shown two portions of the Albula branch of the Rhætian Railways, Canton Graubünden, southeastern Switzerland. The line connects the valleys of the Albula and the Inn, the former being one of the branches of the Rhine and the latter of the Danube; it therefore cuts the divide between the watersheds of those two rivers. It is a 3.28-feet gauge single-track road. and is built largely for tourist traffic, as the scenic properties of the line are remarkable.

The maximum grade on this line is 3.5 per cent. Over one portion of the line 7.8 miles long one third of that distance is in tunnel and 15 per cent of it on viaducts. The radii of the centre lines of the tunnels are 460 and 394 feet, while the lengths of the tunnels range from 1591 to 2250 feet, with a maximum grade in them of 3 per cent. The weight of rails used is 50 pounds per yard on grades of 2.5 per cent or less, but for heavier grades 55-pound rails are employed. The cross-ties are of mild steel and weigh 80 pounds each except in the long Albula tunnel, where

FIG. 8.

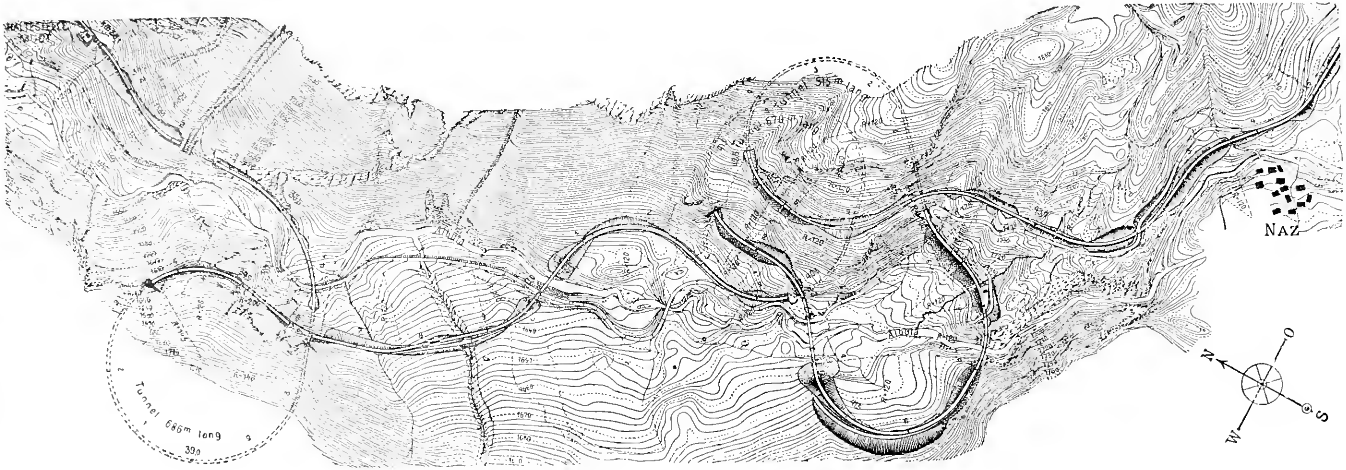


FIG. 9.

treated oak ties are used as being better adapted to the special conditions existing there. It will be observed that in each case the line rises from the left-hand portion of the figure toward the right.

The tunnels are represented by broken lines, and they are in every instance on circular curves. Fig. 9 represents the line running from a point on the east side of the Albula River through a heavy cut and then across the valley of the Albula into a tunnel 2250 feet long. The line then runs chiefly in cuts to a point where there are two tunnels, one over the other; indeed the line overlaps itself in loops and tunnels a number of times in that vicinity. That portion of the road shown in Fig. 8 is less remarkable than the other, although it exhibits extraordinary alignment. This example of railroad location is one of the most striking among those yet completed. It would appear to indicate that no topographical difficulties are too great to be overcome by the civil engineer in railroad location in a most rugged and precipitous country. Obviously such a line could not be economically operated for heavy freight traffic.

Railroad lines frequently lead through mountainous regions affording some of the grandest scenery in the world accessible to the travelling public. In this country the Canadian Pacific, the Northern Pacific, the Great Northern, and the Rio Grande Western probably exhibit the most remarkable instances of this kind.

CHAPTER XXII.

264. Railroad Signalling. — The birth of the art of railroad signalling was probably coexistent with that of the railroad. At the very outset of the movement of railroad trains it became imperative to insure to a given train the sole use of the single track at schedule periods. Both head-to-head and rear-end collisions were liable to occur on main tracks, as well as false meetings at branches and cross-overs.

265. The Pilot Guard.—One of the earliest if not the earliest of systematic procedures in England to accomplish the safe use of a railroad track involved the employment of the "pilot guard" on single-track roads. The pilot was an employé whose duty it was to accompany every tra n over a stated section of the line. The authority to start trains was lodged in him. When it became necessary to start two or three trains from the same point and in the same direction, it was also his duty to issue to each train conductor what was called a pilot ticke , equivalent to a modern train order to run the train over the section under his control. In that case he was obliged to accompany the last train to the other end of his section, and no more trains could move over that section in the same direction until his return to his first station. As no train could pass over the section without either him or his pilot ticket, it is clear that the system could prevent head-to-head collisions, but in itself it is not sufficient to eliminate rear-end collisions. This system is still employed in Great Britain on some short branch lines.

266. The Train Staff.—Another method nearly as old as the preceding is that of the train staff, used in an improved form at the present time on some single-track roads. No train under this system can pass over any given section of the line unless it carries the staff belonging to that section, the staff being a piece of wood or metal 1 to $1\frac{1}{4}$ inches in diameter and 18 to 20 inches long. In order to cover the case of two or more trains starting in the same direction at one end of a section before running a train in the opposite direction, tickets were issued, the staff being taken by the last train. The proper operation of this method, like that of the preceding, would prevent head-to-head collisions, but is not sufficient in itself to prevent one train running into the rear of another while both are proceeding in the same direction in the same section.

267. **First Basis of Railroad Signalling.** — These and other similar systems answered fairly well the more simple requirements of early railroad operation. Strictly speaking they are not methods of signalling, although it may be said that each train is a signal in itself. With the development of railroad business it was found that other methods better adapted to a more efficient and rapid movement of trains were imperative. It was in response to the advancing requirements of the railroad business that the first approach to what is now so well known as the block system of signalling was made in 1842. An English engineer, subsequently, Sir W. F. Cooke, stated the following sound principles as to the basis of efficient railroad signalling:

"Every point of a line is a dangerous point which ought to be covered by signals. The whole distance ought to be divided into sections, and at the end as well as at the beginning of them there ought to be a signal, by means of which the entrance to the section is open to each train when we are sure that it is free. As these sections are too long to be worked by a traction rod, they ought to be worked by electricity."

The main features of railroad signalling, as thus set forth, have continued to characterize the development of the block system from that early day to the present. The electrical application to which reference is made in the preceding quotation was that of the needle, which by its varying position could indicate either "line clear" or "line blocked." In 1851 electric bells were used in railroad signalling on the Southeastern Railway of England. Various other developments were completed from time to time in Great Britain until the Sykes system of block signalling was patented in 1875. One of the main features of the system, and perhaps the most prominent, was the control of the track signals at the entrance end of the block by the signalman at the advance end. He exerted this control by electrically operated locks. About 1876 the Pennsylvania Railroad introduced the block system into the United States, which has since been greatly developed in a number of different forms, and its use has been widely extended over many if not most of the great railroad systems of the country. It is not only used for the movement of trains, but also for the protection of such special danger-points as switches, cross-overs, junctions, drawbridges, heavy descending grades, sharp curves, and other points needing the protection which a well-designed block system affords.

268. Code of American Railway Association.—The code of the American Railway Association gives the following definitions among others pertaining to the block system:

Block.—A length of track of defined limits, the use of which by trains is controlled by block signals.

Block Station.—The office from which block signals are operated.

Block Signal.—A fixed signal controlling the use of a block.

Home Block Signal.—A fixed signal at the entrance of a block to control trains in entering and using said block.

Distant Block Signal.—A fixed signal of distinctive character used in connection with a home block signal to regulate the approach thereto.

Advance Block Signal.—A fixed signal placed in advance of a home block signal to provide a supplementary block between the home block signal and the advance block signal.

Block System.—A series of consecutive blocks controlled by block signals.

Telegraph Block System.—One in which the signals are operated manually upon telegraphic information.

Controlled Manual Block System.—One in which the signals are operated manually, and by its construction requires the co-operation of a signalman at both ends of the block to display a clear signal.

Automatic Block System.—One in which the signals are operated by electric, pneumatic, or other agency, actuated by a train or by certain conditions affecting the use of a block.

268a. The Block.—It is seen by these definitions that what may be called the unit in railroad signalling is the "block"; it may be of almost any length from a few hundred feet to 6 or 8 miles, or even more. On a single-track railroad it may evidently extend from one side track or passing-place to another. Over portions of lines carrying heavy traffic it may be a half-mile or less. The length of block will depend, then, upon the intensity and kind of traffic, the physical features of the line, such as curvature, grade, sidings, cross-overs, and other similar features, the location, whether in cities, towns, or open country, as well as upon other elements affecting conditions of operation which it is desirable to attain.

269. Three Classes of Railroad Signals — The Disc.—The signals used in railroad operation may mainly be divided into three classes: semaphores, banners, and discs. In general they may convey information by form, position, and color. The disc is used by causing it to appear and disappear before an aperture, usually a little larger than itself, in a case standing perhaps 10 or 12 feet high alongside the track, and is admirably typified in the Hall electric signal. On account of its shape, the case in which the disc is operated is frequently called the banjo, as it is quite similar in shape to that musical instrument placed in a vertical position, the key end resting on the ground.

270. The Banner Signal.—The banner signal is usually operated by rotation about a ver ical axis, frequently in connection with switches. Its full face painted red, exposed with its plane at right angles to the track, indicates "danger" or "stop." With its face turned parallel to the track, showing only its edge to approaching trains, a "clear" lin or "safety" is indicated.

In the present development of railroad signalling the banner and disc patterns have a comparatively limited application, although, on the whole, they are largely used. The banner signal is mostly employed in the manual operation of switches, turn-outs, and cross-overs, and for other local purposes, particularly on lines of light traffic.

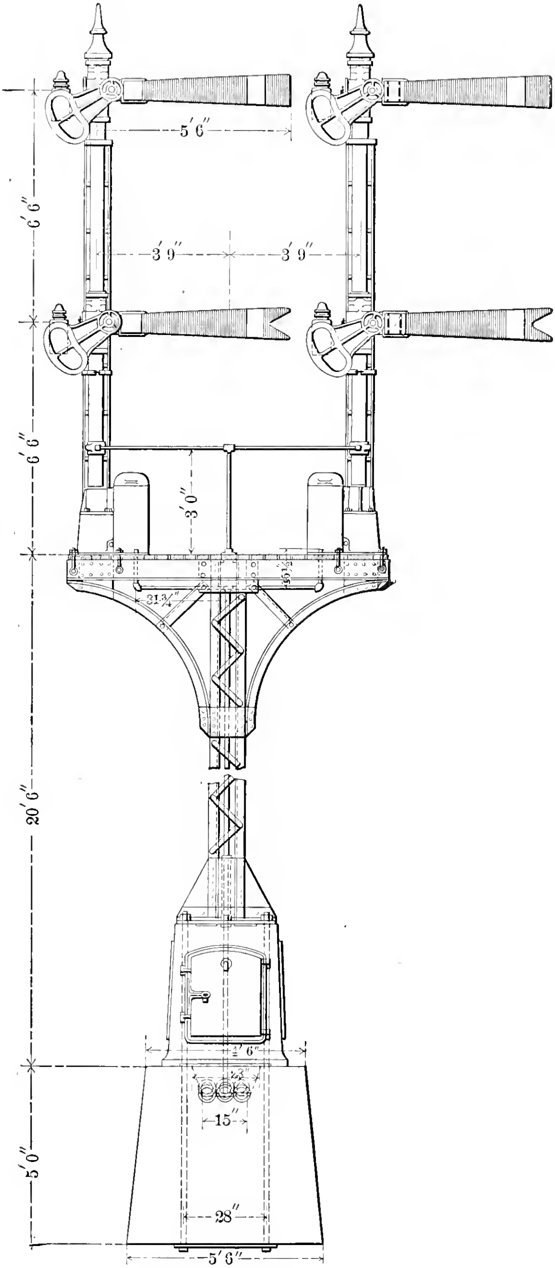


FIG. 10.—Semaphore Signals.

271. The Semaphore.—The semaphore is now mainly used in connection with block signalling. Like many other appliances in railroad signalling it was first used in England, by Mr. C. H. Gregory, about 1841. Its name is derived from the combination of two Greek words signifying a sign-bearer. It consists of a post varying in height from about 3 to 35 or 40 feet, carrying an arm at its top from 3 to 5 feet long, pivoted within a foot or 18 inches of one end, the long end suitably shaped and painted and the other arranged with a lens so that when operated at night in connection with a lamp it may exhibit a properly colored light. The post of the semaphore is placed alongside the track so as to be on the right-hand side of an approaching train, the long arm rising and falling as a signal away from the track and in a plane at right angles to it. The other arm of the semaphore signal

[illegible]

ma be co necte b wires or ro s and light chains nnin o er pulleys with suitable le ers and weights operated either in a near-by signal cabin or by a signalman stationed near the sema phore itself; or it may be operated by electric or pneumatic power, as in any of the later installations. he semaphore may, therefore, be operated at the post or by suitable appliance at a distance.

. **lor or ign l ing.** The colors sed either for painte signals for daylight e posure or for coloring lenses for night signalling are red, hite, and green, as ordinarily employed i this country; red signifying danger ' or "stop ' white signify ing "safety" or "clear track," and green signifying "caution" or "proceed with train under control," indicating that a train may go forward cautiously, expecting to find an obstruction or occupied track. In England green is largely employed to indicate "safety" or "clear track," on the ground that a white light is so similar to any other in its vicinity that the latter may too easily be mistaken for a signal. While there is some diversity of views in this country on that point, the consensus of engineering opinion seems to favor the retention of the white for the track safety signal.

273. Indications of the Semaphore.—It is evident that a semaphore affords facilities of form, position, and color in its use for the purpose of signalling. The horizontal position is the most striking for the semaphore arm, as it then extends at right angles to the post and to the right or away from the track; this position is, therefore, taken to indicate "danger" or stop." No train may, therefore, proceed against a horizontal semaphore arm.

It might at first sight appear that the vertical position of the semaphore arm close against the post could be taken to indicate "safety" or "clear track" or "proceed," but experience has shown that such a position may be injudicious, except under special conditions where it has lately been employed to make that indication. If the semaphore arm should be knocked or blown from the ordinary post, the engineman of an approaching train probably would not be able to detect the actual condition of things and might accept the appearance of the semaphore as indicating a clear line, thus justifying himself in proceeding at full speed, while the signalman in his cabin might have placed the signal at "danger." A position of the semaphore arm, therefore, at an angle of 65° or 70° below the horizontal is usually taken as a safety signal. This position is in marked contrast to the horizontal arm and at the same time makes the absence of the semaphore arm impossible without immediate detection from an approaching locomotive. After dark the semaphore in a position of danger exhibits a red light through the lens in its short arm when the long arm is at the "danger" position or horizontal. Similarly, when the long arm is in the safety position a white light is exhibited through the lens in the shorter arm, so that the respective conditions of clear or obstructed track are made evident to the engineman as well by night as by day on his approach to the semaphore.

In some of the latest signal work three positions of the semaphore arm on one post, known as three-position block signalling, have been employed. In this system a special post, frequently on a signal bridge over the track, permits the vertical position of the semaphore arm to indicate "clear track," while the diagonal or inclined position below the horizontal indicates "caution." In the Mozier three-position signal a diagonal or inclined position above the horizontal indicates "caution" an addition to the two usual positions of "stop" and "clear."

These are the elements, so to speak, of railroad signalling at the present day. They are combined with various appliances and in various sequences, so as to express all the varied conditions of the track structure which affect the operation of the road or the movement of trains upon it. These combinations and the appliances employed in them are more or less involved in their principal features and complicated in their details, although the main principles and salient points are simple and may easily be exhibited as to their mode of operation and general results. In this treatment of the subject it will only be possible to accomplish these general purposes without attempting to set forth the mechanical details by which the main purposes of railroad signalling are accomplished.

274. General Character of Block System.—It is evident from what has already been stated that the block system of signalling involves the use of fixed signals located so as to convey promptly to approaching trains certain information as to the condition of points of danger approached. Furthermore, this system of signals is designed and operated on the assumption that every point is to be considered as a danger-point until information is given that a condition of safety exists. The usual position of signals, or what may be called the normal position, is that of "danger," and no position of "safety" is to be given to any signal except to permit a train to pass into a block whose condition of safety or clear track is absolutely assured. These are the ground principles on which the signal systems to be considered are designed and operated, although there are some conditions under which the normal signal position may be that of safety.

275. Block Systems in Use.—The block systems now in general use are:

The Manual, in which the signals at each end of each block are wholly controlled and operated by the signalman at each signal point.

The Controlled-Manual, in which the signals at the entrance to each block are controlled either electrically or in some other manner by the signalman at the other extremity of that block, but are operated subject to that control by the signalman at the entrance of the block.

The Auto-Manual, in which the signals are generally operated and controlled as in the Manual or Controlled-Manual, except that they are automatically returned to the danger position as the rear car of a moving train passes them.

The Automatic, in which the operation of the signals is wholly automatic and generally by electricity, or by a combination of electric and pneumatic mechanism. In this system no signalmen are required.

The Machine, which is a controlled block system for single-track operation and in which machines operated electrically with detachable parts, as staffs, are employed in connection with other fixed signals alongside the track.

The main features of these various systems of blocking are, in respect to their signalling, the same, but the means for actuating or manipulating the signals and the conditions under which moving tra ns receive the necessary instructions are different. They all have the same main objects in view of improving railroad operation by enhancing both safety and facility of train movement.

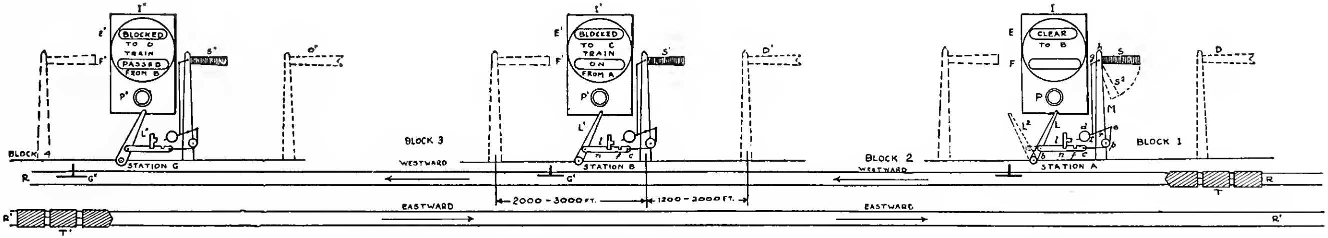
"Absolute" blocking is that system of block signalling which absolutely prevents one train passing into a block until the preceding train is entirely out of it, or, in other words, until the block is absolutely clear.

"Permissive" blocking is, strictly speaking, the violation of the true block system of signalling, since under it a train may

of three signals—the distant, the home, and the advance—taken in the order in which the moving train finds them, is located at each extremity of the block. Although the home signal is said to control the movement of trains in a block at the entrance to which it is found, as a matter of fact it appears that the advance signal in the final event holds that control.

278. Typical Working of Auto-Controlled Manual System.—The mode of employing these signals can be illustrated in a typical way by the diagrams, Figs. 11, 12, and 13, which exhibit in a skeleton manner Pattenall's improved Sykes system which belongs to the Auto-Controlled Manual class. In these figures the end of block 1, the whole of blocks 2 and 3, and the beginning of block 4 are shown. Stations *A*, *B*, and *C* indicate the extremities of blocks. The signals S, S', and S'' are the home signals, while D, D', and D'' indicate distant signals, and A, A', and A'' advance signals. As the diagrams indicate, the stretch of double-track road is represented with east- and west-bound tracks. In order to simplify the diagrams, signals and stations are shown for one track only; they would simply be duplicated for the other track. The signal cabin is supposed to be located at each station, and at that cabin are found the levers and other appliances for working the signals operated there, the signals themselves being exposed alongside the track. In each signal cabin there is an indicator, as shown at I, I', and I''. On the face of each indicator there are two slots, shown opposite the lines *E* and *F*. In the upper of these slots appears either the word "Clear" or "Blocked." In the lower slot appears either the word "Passed" or "On." The significance of these words will appear presently. On this indicator face at P, P', and P'' are located electric push-buttons called plungers. The operation of the levers indicated at *L*, the counterweights *d*, and the locking detail *l* are evident from an inspection of the figure, and need no special explanation. It is only necessary to state that the locking-device *l* holds the bar *bc* until it is released at the proper time, and that the counterweight may then return the lever from its extreme leftward position to that at the extreme right, at the same time placing the semaphore arm *S* in the position of danger. It is particularly important to bear in mind

FIG. 11.



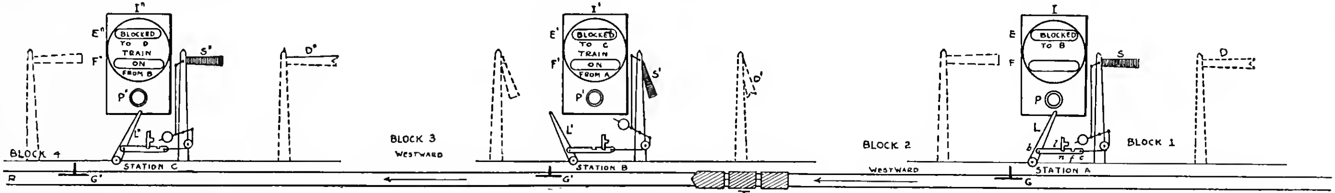


FIG. 12.

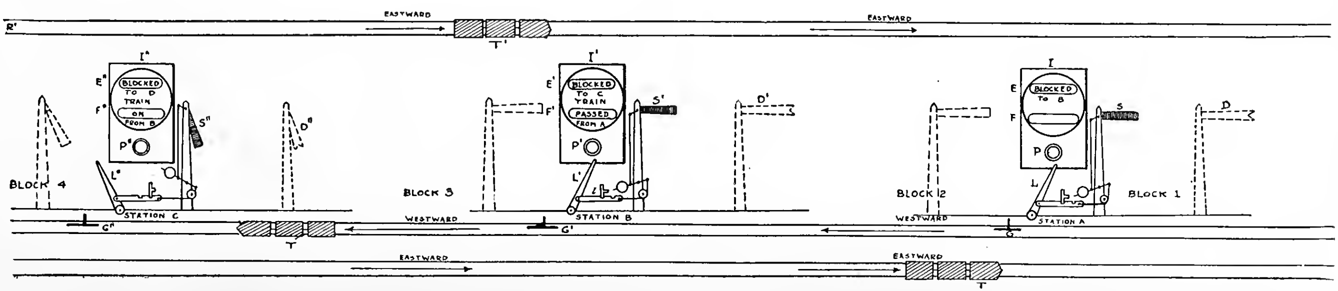


FIG. 13.

this last observation. The counterweight is the feature of the system which always holds the semaphore arm in the position of danger, making that its normal position, except when it is put to safety for the passing of a train.

If a westward train is represented in Fig. 11 at *T* as approaching station *A* to enter the block 2, both the distant signal *D* and the home signal *S* being at danger, the system is so arranged that the signalman at station *A* cannot change those signals, i.e., to a position of safety, until the signalman at station *B* permits him to do so. If the signalman at station *A* desires to open block 2 for the entrance of the train *T*, he asks the signalman at station *B* by wire to release the lock *l* to enable him to do so. If there is no train in block 2, the signalman at station *B* pushes the button *P′* or "plunges" it. This raises the lock *l* at station *A* and the signalman immediately pulls the lever *L* to its extreme leftward position, throwing both the signals *S* and *D* to the position of safety or clear, indicated by the dotted lines at S^2. At the same time the indicator *E* at station *A* shows the words "Clear to *B*," while the slot *F′* at *B* shows the words "On from *A*." The signals at stations *B* and *C* are supposed to be in their normal position of danger, and the indicator *E′* at station *B* shows the words "Blocked to *C*." The home and distant signals *S′* and *D′* are now at danger, but the train *T* may enter block 2 and proceeds to do so, it being remembered that the signalman at station *A* cannot move the lever *L*, as it has passed out of his control; not even the signalman at station *B* can give him power to do so. The train *T* now passes station *A* into block 2. As the last car passes over the point *G* its wheels strike what is called a track-treadle, an appliance having electrical connection with the lock *l*. The effect of the wheels of the last car of the train passing over the treadle at *G* is to release lock *l*, enabling the signalman at station *A* immediately to raise the arms *S* and *D* to the position of danger. It is to be observed that he cannot do this until the entire train has passed into block 2; nor, since his plunger is locked by the same treadle at *G*, can he signal "Safety" or "Clear" to the entrance of block 1. Hence no train can enter block 1 to collide with the rear end of the train just entering block 2. When the signalman at station *A* has raised his signal *S* to danger, it again passes out of his control, indeed out of both his control and that of the signalman at *B*, until the last car of the train passes over the treadle *G'* at the entrance of block 3.

The train has now passed into block 2 and is approaching station *B*. The signalman at *B* asks *C* by wire to release the lever *L'*, and if block 3 is clear, *C* plunges at *P''*.

C then throws his lever *L'* so as to place the home and distant signals *S'* and *D'* at safety. The condition of things will then be shown by Fig. 12. As soon as the last car of the train has passed over the treadle at *G'* his lever *L'* will be released and he can then throw the lever to the danger position, raising the home and distant signals *S'* and *D'* to the horizontal. After the danger position is assumed by the home signal *S'*, as well as the distant signal *D'*, he has no power over them until the signalman at station *C* confers it on him by plunging the button *P''*.

While the train has been in block 2, the indicator *I'* has shown "Blocked to *C*" and "Train on from *A*," but as the train passes *B* the indicator reads "Blocked to *C*" and "Train passed from *A*," while the indicator *I''* at *C* reads "Blocked to *D*" and "Train on from *B*." This condition of the signals and trains is shown by Fig. 13. Also, when the last car passes over the treadle *G'*, but not till then, *B* may permit *A* to admit a train to enter block 2 should *A* so desire. Finally, when the train approaches *C*, the signalman at that point asks *D* to enable him to permit the train to enter block 4, and *C* confers the power by plunging if that block is clear. Fig. 13 exhibits the corresponding signals at *C*.

This sequence of operations is typical of what takes place in this particular block-signal system at the limits of every successive block, and differs only in details characteristic of this system from those which are performed in any other block-signal system.

279. **General Results.**—It is seen first that no signalman can operate a signal until the condition in the block ahead of him is such as to make it proper for him to do so, and then he can only indicate what is necessary for the safe entrance of the train into that block. Furthermore, immediately on the passage of the train past his home signal he must put the latter to danger

or the counterweight may do it for him, the train itself when in a safe position having conferred the requisite power upon him. The signalman at the advance end of the block always knows when the train is about to enter it, for he is obliged to give his permission for that entrance. His indicator shows this result, and will continue to show it until the train passes out of the block. It is to be observed that the upper openings marked *E* on the indicator give information of the condition of the block in advance, while the lower openings give information of the block in the rear.

It is particularly important to notice that after the signalman at the advance end of a block has "plunged" his plunger remains locked and it cannot be released until the train admitted to the block covered by the plunger has completely passed out of that block, permitting the track-treadle at the entrance to the next block to unlock the plunger. This feature makes it impossible for one train to enter a block until the preceding train has passed out of it.

If the permissive system of using a block be employed, in which the train is permitted to enter that block before a preceding train leaves it, the treadle gives no protection against a rear-end collision with the first train. In such an exigency other devices must be used or the following train must proceed cautiously, expecting to find the track occupied.

280. Distant Signals.—Thus far the distant signals have been treated incidentally only. They may be operated concurrently with or independently of the home signal in such a way that if danger is indicated, the distant signal gives its indication prior to that of the home signal. In this manner protection is given to the rear of a train approaching a block against the home signal set at "danger." After the obstruction is removed and the block cleared, the home signal is set at "safety" before the distant signal is cleared.

281. Function of Advance Signals.—The advance signals are used when for any purpose it is desired to form a short block in a regular block. If, for instance, block 3 in Fig. 11 were obstructed by a train stopped by some failure of a locomotive detail, a train approaching station *B* in section 2 against the home signal *S′*

set at "danger" would be obliged to stop before entering block 3. It might then be permitted to enter the latter block, to be stopped by the advance signal *A′* set at "danger" or under instructions to pass it cautiously, expecting to find the track obstructed. It is thus seen that the advance signal creates what may be called an emergency block, and in reality finally controls the movement of trains in the block in which it is located. It would never be cleared unless the home signal were first cleared, nor would it be set at "danger" unless the home signal gave the same indication.

The preceding operation of the block system of signalling controls the movement of trains along a double-track line.

282. Signalling at a Single-track Crossing.—A somewhat similar sequence of signal operations controls train movements at a crossing, whether single- or double-track. Fig. 14 illustrates the

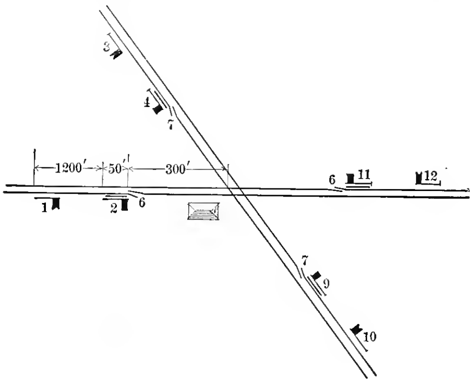


FIG. 14.

use of signals required for the safe movement of trains at a single-track railroad crossing, which is supposed to be that of a north-and-south line crossing obliquely an east-and-west line. Precisely the same arrangement of signals operated in the same manner would be required if the crossing were at the angle of 90°. The signal cabin is placed, as shown, as near as practicable to the actual intersection of tracks. Trains may pass in either direction on either track, but in every case they would be governed by the signals at the right-hand side of the track as seen by the engineman. There will therefore be a set of signals on both sides of each track, each set governing the movement of trains in its own direction. Each home signal may be placed about 350 feet from the actual intersection, and each distant signal 1200 to 1500 feet from the home signal, or 1550 feet to 1800 feet from the intersection. Each advance signal must be at least as far in advance of the home signal as the maximum length of train, since it may be used to stop a train, the rear car of which should completely pass the home signal. In their normal positions every home signal should be set at "danger," carrying with them the distant signals giving the same indication. The advance signals must also indicate "danger" with the home signal. No train can then pass the crossing until the home and distant signals indicate a clear line for it, the other signals at the crossing, except possibly the advance signal, being set at "danger." If for any reason it is desired to hold the train after it is entirely free of the crossing, the advance signal would also indicate "danger."

It is thus seen that if the signals are properly set and obeyed, it is impossibl for two trains to attempt a crossing at the same time. It is not an uncommon occurrence, however, for an engineman to run his train against th danger signal, and in order to make it impossible for the train to reach the crossing even under these circumstances a derailing device is used. This derailing arrangement is shown in Fig. 14, about 300 feet from the crossing, although it may be placed from 300 to 500 feet from that point. Its purpose is to derail any train attempting to make the crossing against the danger signal. The operation of the derail is evident from the skeleton lines of the figure. When the home signal is at danger the movable part of the derailing device is at this point turned so as to catch the flanges of the wheels as they attempt to pass it. The train is thus thrown upon the cross-ties at such a distance from the crossing as will produce a stop before reaching it. When the home signal is at safety the derail operated with the signal is closed and the line is continuous. This combination of signals and derail coacting serves efficiently to prevent collisions at crossings, although trains may be occasionally derailed in accomplishing that end. The preceding explanations of the use of signals and derail apply to a train that may approach the crossing in either direction on either track, as is obvious from an inspection of the diagram itself.