and is of high electrical conductivity. The cast iron *l* is approximately 100 pounds in weight and covers the rails for a length of 10 or 12 inches.

37. Electrically Welded Joints.—In this method of joining the rails, the abutting ends are first cleaned and then held by a special arrangement, by means of which they may be pressed together after they have been brought to a welding heat. A heavy current is then sent through the joint until it becomes heated. This current is usually furnished by a special welding transformer that is capable of delivering a very large current at low pressure. This transformer is usually supplied with alternating current that is obtained from a rotary transformer or motor generator, operated by the 500-volt trolley current. The electrically welded joint has a very low electrical resistance if the work is properly done. It is, however, hardly as strong mechanically as the cast-welded joint, unless it is reenforced by side pieces. The cast-welded joint is used more widely than the electrically welded joint, but the great majority of roads use the regular fish-plate joint.

THE TRACK.

38. General Remarks.—There is no class of track work that calls for more care and attention to details than that for a track on which cars equipped with heavy electric motors are to run. There are two general ways of propelling street cars over the road. One way is by means of a force outside of the car itself, as found in the cable road; and the other is by means of a force applied directly to the car axles, as on cars propelled by air, steam, and electric motors. The latter way has the advantage that each car is an independent unit, so that trouble on one does not necessarily interfere with the running of the rest. But, on the other hand, the wear and tear on the track on an axle-driven system is much greater than it is on a cable system. This is due not only to the increased weight of the independent unit incidental to its carrying all its own driving devices, but to the continual slippage of the wheels and hence grinding effect that takes place under certain conditions. This latter point is proved by the fact that on grades the up-going rail always wears out first, because this is the track on which the most spinning of the wheels takes place. This effect is often noticeable on the head of the rail, even on level track; the rail looks as if some one had gone along with a small emery wheel and ground the rail top into a series of arcs of circles—quite small, it is true, but plainly noticeable. Added to these two features is that of the much higher rate of speed at which self-contained cars run. As a result of all these influences, whenever a horse-car line is converted into an electric line, it is in most cases necessary to change not only the weight and style of the rail used, but the whole roadbed construction. Great care has to be taken to support the joints between the ends of the abutting rails in a thorough and substantial manner, because it is here that the pounding takes place and the greatest wear occurs. An electric road requires the exercise of even more care in the perfection of its track work than any other kind of road, because not only are the rails a part of the electrical circuit in most cases, thus making it necessary that they be electrically continuous from one end of the line to the other, but the life of the overhead work and the rolling stock is indirectly but very largely dependent on the quality of the track.

In order to get the best electrical results out of the rail as a return conductor, the joints should be able to carry a current with as little loss of energy as the same length of the rail itself. There are means provided for securing this condition when the track is new, but no means can be provided for preserving the electrical continuity if the joints are allowed to run down and become loose. If the joints are good and the rail is smooth, there will be no trouble in keeping the trolley pole on the wire, unless there is a defect in the pole or wire itself. Such a trouble would be local and easily remedied. But if the joints are bad, there will be no end of trouble, due to the pole jumping off the wire.

Nothing is harder on trucks and car bodies than a bad track; the pounding and jolting loosen the truck and motor bolts, wreck in course of time the suspension rigging and let the motor down on the pavement; it causes excessive teetering, setting of springs, and breaking of axles; it is hard on the bearings and just as hard on the brushes, with the result that the commutator soon gets in bad shape and troubles from flashing, grounds, and open circuits begin.

39. The kind of roadbed and rail to be used depends on where the road is located. If the soil has a very poor bottom, such as is the case in New Orleans, La., the subwork of the roadbed must be much more substantial than there is any need to be on soil that is firm and lays on a rock bottom, such as is found in New York. Where the proposed road runs through the country, it is the custom to use a **T** rail; in cities, on paved streets, the girder rail is used; but on account of its easy riding qualities and less cost, the trend is towards the use of the **T** rail wherever it is possible.

It is a well-known fact that in sections where the wagon traffic is heavy, the rail gets a great deal of its wear from this traffic. All light and medium vehicles are built to standard gauge to fit the track, and the heavier ones of wider gauge run with one wheel on the rail while the other one cuts a groove alongside of the other rail. To offset any inducement that the rail might naturally offer to wagon traffic, the plan was adopted of so shaping the rail and so bringing the paving up flush with its head, both inside and outside of the track, that there would be very little tendency for the wheels to follow the line of the rail. Wagon traffic takes the path of least resistance; one way, therefore, to lessen the traffic on the rail is to make the paving on both sides of it good.

40. Staggered Joints.—In placing the rails, opinion is divided as to how the joints should be disposed; some engineers are in favor of staggering the joints, while others prefer to put the joints opposite each other. The natural advantage of the broken or staggered plan is that if the joints are in poor condition, the jolting of the car is not as severe passing over them one side at a time as it is passing over both sides at the same time, as is the case with the joints opposite; on the other hand, when the joints are staggered and are in bad condition, the car, especially if it is a long body on a single truck, acquires a disagreeable side rolling motion, very much like the motion due to a sprung axle. On double-truck cars the effect is not so marked. The general practice is, however, to use staggered joints.

While the importance of making the track as good as possible has been realized for many years, it is only within the last few years that tracks have been constructed to withstand the hard usage to which motor cars subject them. Even high-grade concrete meets with liberal use in the subwork of such roads. The steel cross-tie threatens to take the place of the wooden one, and the old-style tie-rod is giving way to a tie-beam as large as the rail itself.

THE ROADBED.

41. The permanent character of the track as a whole depends greatly on the character of the roadbed; if after the substructure is laid, it gives or swerves in places, everything that rests on it gives and swerves also, so that in course of time the surface of the track becomes undulating and serpentine in outline. Electric roads as far as possible now follow steam-road practice in their roadbed and track work, and for out-of-town work they could not do better. Fig. 40 shows a standard steam-road construction. The same care and exactness that are observed in steam-road construction should be observed in electric railroading, where the train speeds are often almost as high and other conditions just as severe.

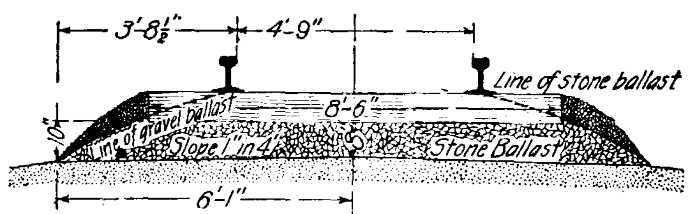

FIG. 40.

42. Methods of Installing Electric Roadbeds.—On suburban electric roads, the steam construction can be followed closely. It frequently happens, however, that electric roads are run in streets that if not already paved will be at some future time, and hence the conditions are somewhat changed. The methods of building electric roads differ so radically that it can be truly said that the only elements of construction in common to all electric roads are the earth and the rails. Some roads have wooden cross-ties, some metal, and others have no cross-ties at all. One road must build an expensive substructure for its roadbed and another, on account of natural conditions, may not have to lay scarcely any roadbed. There can be no better way of bringing out these several points in construction than to take examples of roads on which they occur; but before doing this, we will consider the most common forms of rail in use and the conditions to which they are best adapted.

RAILS.

43. T and Girder Rails.—There are two kinds of rail in common use, the **T** rail and the girder rail, both of which

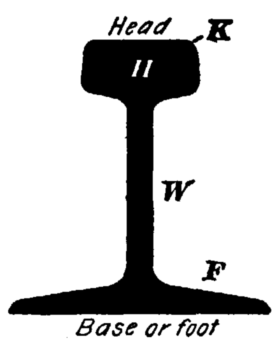

FIG. 41.

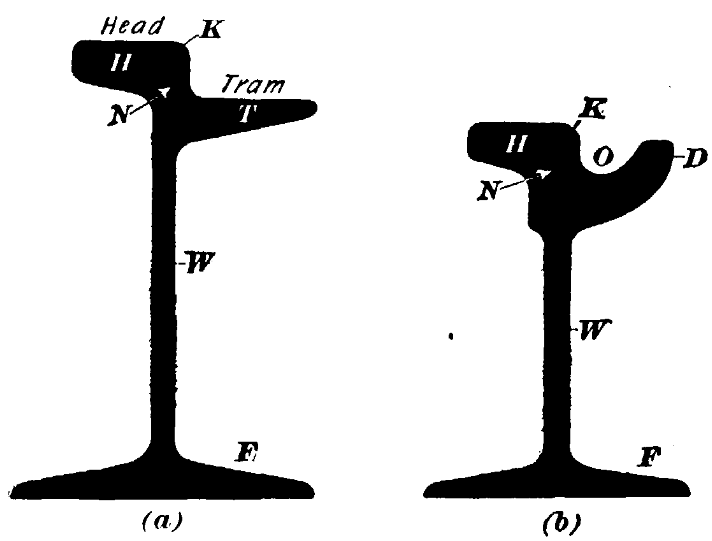

FIG. 42.

get their names from their general shape. Fig. 41 shows a type of **T** rail used for cross-country, suburban, elevated, and underground roads, where the wagon traffic does not have to be considered. *H* is the head, or ball, of the rail, *W* is the web, and *F* is the flange, or foot. A **T** rail is called a center-bearing rail, because the center of the head is directly over the center of the web. Fig. 42 (*a*) and (*b*) shows two types of girder rail ; (*a*) is known as a **tram rail** on account of the tram *T* and (*b*) is known as a **grooved rail,** because it has the groove *O*. In Fig. 42 (*a*) and (*b*), *H* is the head ; *W*, the web ; *F*, the flange, or foot; *N*, the neck; *D*, the lip; and *K*, the gauge line or line that the heel of the gauge touches when gauging the distance apart of the rails. The tram rail is the first in order of invention, and it is still more used than any other type of girder rail.

44. Grooved Rail.—The grooved rail was introduced as a means of diverting wagon traffic from the rail, and in this it has succeeded quite well ; but in the earlier forms of grooved rail, it was found to be a source of constant trouble to keep the ice, dirt, and stones out of the groove. The presence of this foreign matter not only increased the power required to run the car, but it also introduced an element of danger, as a small stone could throw the car off the track. In modern grooved rails, however, such as that shown in Fig. 43, this bad feature is very much mitigated by the shape given to the groove. For a given groove, there is always a given shape of car-wheel flange that is best suited to that groove ; so that in buying car wheels, due regard must be had for the shape and size of the groove that they are to run in, otherwise there will be excessive wear in the groove and on the wheel flange. A wheel flange must be of a certain depth in order to be safe ; if the depth of the groove and the depth of the flange of the wheel are about the same, the least bit of wear in the tread of the wheel will let the weight of the car down on the flange, where it is not intended to be and which will not

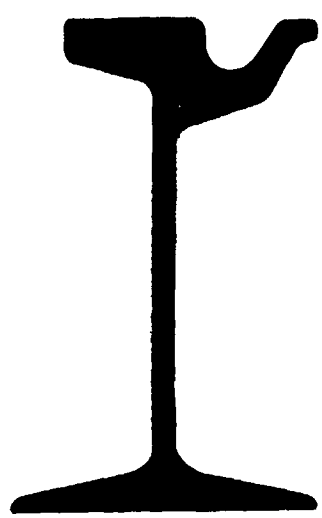

FIG. 43.

stand it; if the wheel flanges are deeper than the groove, the wheels cannot be used at all. A track of grooved rail must be gauged to exactness, because it offers two chances for the wheels to bind. If the gauge is too narrow, the outsides of the wheel flanges bind against the heads of the rails; if the rails are too far apart, the insides of the wheel flanges bind against the side of the groove.

45. Standard Track Gauge. — The standard track gauge is 4 feet $8\frac{1}{2}$ inches, as measured by means of a gauge such as that shown in Fig. 44 (*a*). The car wheels are pressed on the axle to 4 feet $8\frac{1}{4}$ inches by means of a gauge similar to that shown in Fig. 44 (*b*). To apply such a gauge correctly, one end of the gauge should be free to move laterally about $2\frac{1}{2}$ inches, when both of the notches engage the flanges of the two wheels. **T** rails are much more economical from the operating point of view than girder rails, because however much the tread of the wheel may wear down or be ground down there is nothing for the flange of the wheel to ride on.

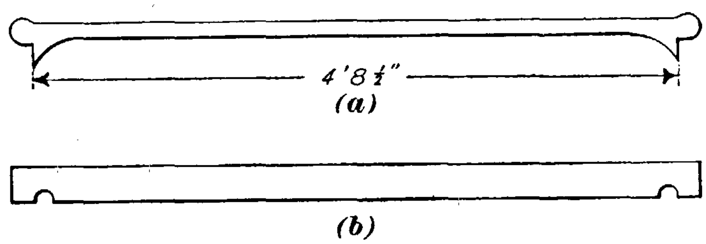

FIG. 44.

46. Rails With Conical Tread.—The treads of wheels are conical; that is, the diameter of tread next to the flange is larger than its diameter at the outside edge. This is done to allow the car to center itself on the track when the two wheels on the same axle are of different sizes. The device probably performs its function when there is no greater difference in the wheels than is found on two wheels of the same make just as they come from the foundry; this difference is, as a rule, not more than $\frac{3}{8}$ inch in the circumference. But the beveled tread cannot be expected to amount to very much as an equalizer where the difference in diameter of the two wheels is $\frac{3}{8}$ or $\frac{1}{2}$ inch. Such a state of affairs should not be allowed to exist, on account of the slippage it causes and for other reasons; but, unfortunately, in some cases it does exist. The general rule has been to make the top of the rail level, with the result that until there is a certain amount of wear in either the rail head or

FIG. 45.

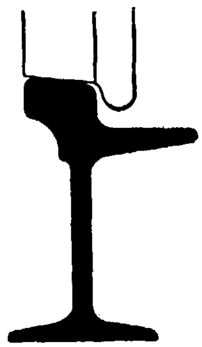

FIG. 46.

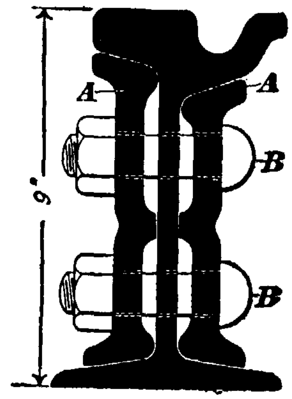

FIG. 47.

the wheel tread, the traction surface between the two is a straight line. In conformity with the observed fact that the side of the rail head next to the gauge line always wears down first, to meet the bevel of the wheel, the very sensible idea is now being practiced of making the top of the

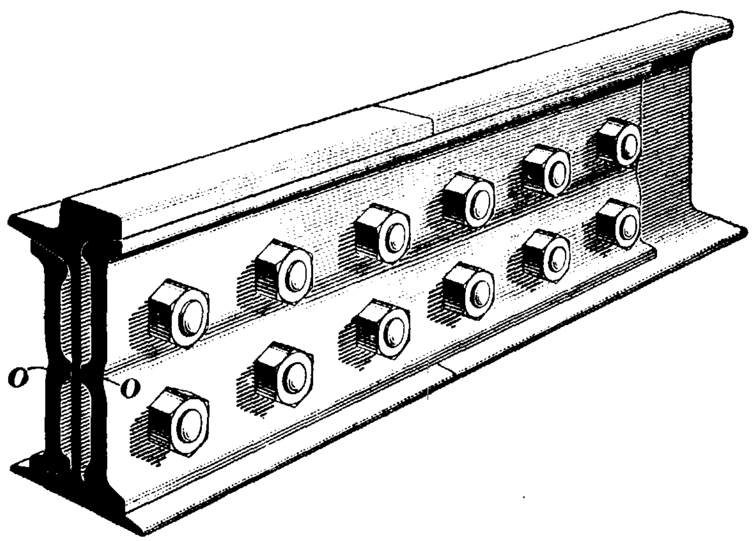

FIG. 48.

rail head also beveled to conform to the bevel on the wheel tread; the result is that the rail and wheel are a fit to begin with and do not have to wear down to that condition. This construction is said to effect a saving of about $33\frac{1}{3}$ per cent. in the life of the wheel and rail. Fig. 45 shows a girder rail with a straight top; Fig. 46 shows one with a bevel top. Fig. 47 shows a section through a complete girder-rail joint. *A*, *A* are the **splice bars,** or **fish-plates,** so designed that they stiffen the joint. They are held up to the rail by **track bolts** *B*, *B*, which pass through the web of the rail. Fig. 48 shows a completed joint. Note the cross-section of the fish-plate; the rib at *O*, *O*, when the track bolts are screwed home, gives somewhat the effect of a lock washer and at the same time insures a definite contact surface between the plate and the rail. There are a great many patented devices in use for stiffening the joint and giving it solidity, and all of them have some merit; but the device that seems to be gaining the most favor with railway men is the cast-welded joint, which has already been described.

47. Guard Rails, Curves, and Special Work.—All roads have a greater or less number of crossings, curves, branch-offs, cross-overs, etc., and since these are different from straight track, in that they involve special care and precautions in their installation, they are all included under the general name of **special work.** Important special work is made up complete at the steel works and is shipped ready to install. When the work is in several pieces, ends that go together have the same mark, so that the trackman can make no mistake in his hurried efforts to complete the job without interfering with regular traffic. As the work of making up special work must be carried out with great precision (a difference of $\frac{1}{4}$ inch in the angle at which one arm of a frog or crossing sticks out may cause no end of trouble), it is carried out step by step, as follows: The site of the proposed work is first measured up carefully and a drawing of the survey made. This drawing is then carefully checked up and is used as a means to lay the work out in actual size with chalk on a hard, smooth, maple floor, known as the laying-out floor; if the job checks up all right, the floor lines and angles are used as a guide for making wooden templets to be used by the patternmaker and the rail bender. When the separate parts of the job are complete, it is set up in the laying-out yard, where any slight errors or inaccuracies due to uneven shrinkage in the cast parts of the job or to want of care in the bending are detected.

In the switch, frog, and crossing part of special work, the greatest wear takes place at the points and breaks. On this account, several schemes have been adopted for not only increasing the hardness of the metal at these places, but for

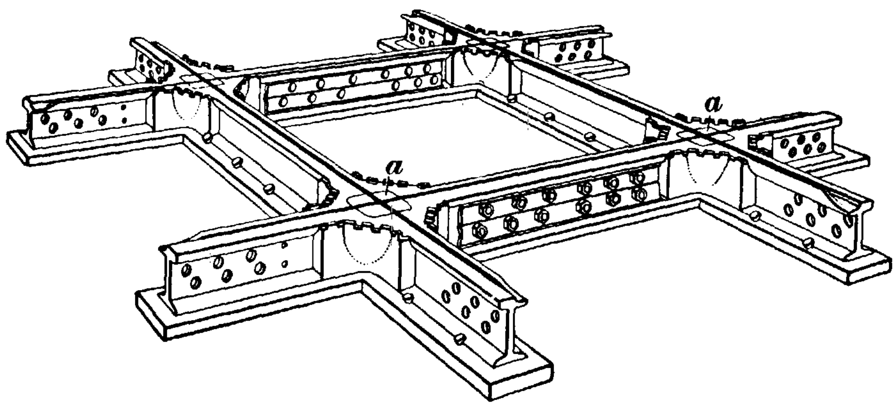

FIG. 49.

making the support stronger, so that the effect of the pounding will be less. There are many different styles of this intersection work. Fig. 49 shows one make of crossing, and the other makes are much the same in general appearance. Hardened centers *a* of manganese steel or other hard kind of steel are used at the points to prevent wear and hammering-out.

48. Curves.—Curves are of two kinds, **simple** and **compound,** or **transition,** curves. A simple curve is one that is described with but one radius throughout its length. A compound curve is one so constructed that the radii becomes shorter as the middle point of the curve is approached from either end. A compound curve is easier riding than a simple curve. Street-railway curves are always designated by the radius at the center. Long curves of light rail are sprung in, as a rule, that is, the rail is pried over with a bar and spiked into position, the paving being relied on to keep the track in place. The main objection to "springing in" a curve is, that if done on a curve of too short a radius or with heavy rail, the job in course of time will give trouble at the joints; the ends of the rails straighten out and make an angle at the joint. This means that the car trucks in rounding such a curve will change direction in jumps, instead of gradually, and impart to the car a disagreeable, jerky motion not to be found on a curve that is smooth and regular. On curves of heavy rail and moderate radius, a portable rail bender should be used, while shorter curves should be bent to a templet with a power bender.

49. A very important point about laying out a single-track curve is to be certain that a car will go around it freely without either end overhanging the corner of the sidewalk or striking any obstruction. On double-track curves is also introduced the feature of two cars being able to pass each other without danger. It is not absolutely essential that the curves be such that two cars can pass each other on them, and in many existing cases it cannot be done. Very often, however, it involves but a small additional cost to so construct the curves that the cars can pass, and it is in the long run the best thing to do. Whether or not a curve will allow cars to pass on it depends on the following: the length of the car; the width of the car; the amount that the ends overhang the wheel base; the distance between the track centers; the curvature; the elevation of the outside rail; the length of wheel base; and, on double-truck cars, the distance between trucks. Also, the matter of fenders should be taken into account, as a fender increases the effective length of the car. As the trucks on a double-truck car are relatively nearer the ends of the car, the overhang in the center must be considered. The best plan is to lay out on paper and to scale a plan of the proposed curve; then, by means of a pasteboard dummy that scales the dimensions of the outside lines of the car, the actual clearance at all points can be readily determined. The positions of the car wheels must be indicated by holes through which the track can be seen, or transparent paper must be used, so that the dummy can be made to take the right path around the curve. Another point to be looked after in cutting out a dummy to try on paper is to see that the widest part of the car is represented. To insure some degree of safety to the heads and arms of passengers, the clearance on both sides of the car should be at least 12 inches, if they are to pass each other on curves. Special attention must be paid to this feature where the center-pole method of line construction is used. There are many roads on which the curve clearance is not over 2 or 3 inches, but in most of such cases there is a rule against passing on curves.

50. Transition, or Compound, Curves.—These curves are formed by combining curves of different radii, so that the entrance of the car into the curve shall be gradual and a sudden shock avoided. The theoretically correct method

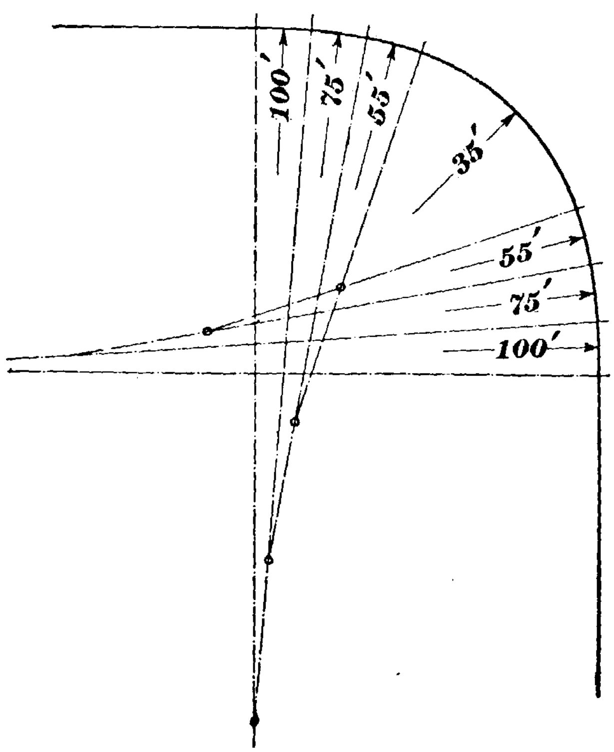

FIG. 50.

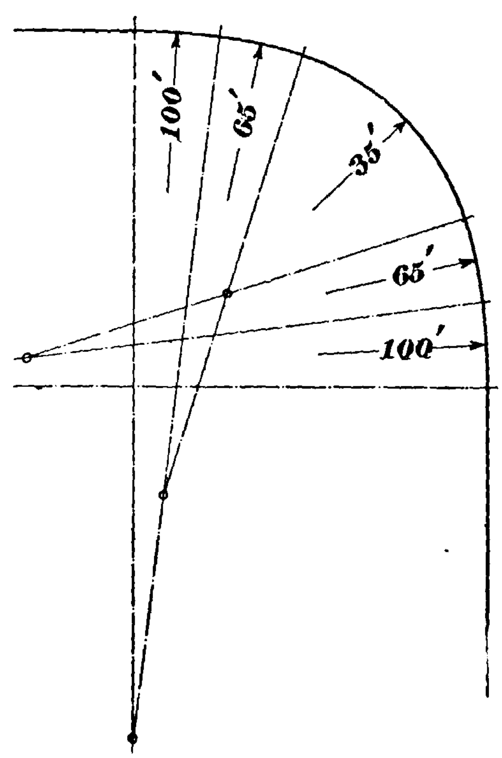

FIG. 51.

of laying out a curve would be to make a true spiral connection between the end of the straight track (called the tangent) and the center of the curve, but this would be practically impossible. Some engineers advocate a near approach to such practice by starting with a radius of some 600 feet or more and changing the radius every 2 feet, as measured along the track, when laying out the approach to a main curve of, perhaps, 35 feet radius. Such frequent change of radius would be very difficult for a trackman to accomplish, and would probably not be done; it is sufficient to change the radius at distances equal to the length of the wheel base, an initial radius of 100 feet being large enough for street-railway work. It is not easy to construct switches for a greater radius, and since they are used on probably 50 per cent. of the curves, this must be taken into consideration. In Fig. 50 the transition curves for a main radius of 35 feet are shown. Each chord, or length of curve having the same radius, is about equal to the wheel base of the cars, and there are three curves completing the transition, having radii, respectively, of 100, 75, and 55 feet. Fig. 51 shows a curve with only two transition curves. In both cases the initial curve has a radius of 100 feet, and the remaining curves should be divided equally between that radius and the radius of the main curve. Thus, for the curve forming the junction of the 100-foot and 35-foot curves, a radius of 65 feet, about midway between these numbers, is taken.

51. Designation of Special Work.—Fig. 52 (*a*) shows a *plain curve*, in the sense that it is not complicated by any branch-offs, turnouts, or other special features. Such a curve can be simple or compound, single or double, right-hand or left-hand. Fig. 52 (*b*) shows a *left-hand branch-off* and Fig. 52 (*c*) a *right-hand branch-off;* these are used where a branch road leaves the main line. Facing the point of departure of the branch from the main line, a right-hand branch-off turns to the right and a left-hand branch-off to the left. Fig. 52 (*d*) is known as a *connecting curve and crossing*. In the figure, the curve is a right-hand branch-off to the horizontal straight track and a left-hand branch-off to the vertical one. Fig. 52 (*e*) is what is known as a *plain* **Y**. Fig. 52 (*f*) is a *three-part* **Y** and Fig. 52 (*g*) a *through* **Y**. The three-part **Y** can be used instead of a loop to turn single-end cars at the end of the line. Fig. 52 (*h*) is known as a *reverse curve*, and must often be used where a cross street is broken at the main street. Fig. 52 (*k*) is a *right-hand* and Fig. 52 (*l*) a *left-hand cross-over*, used to

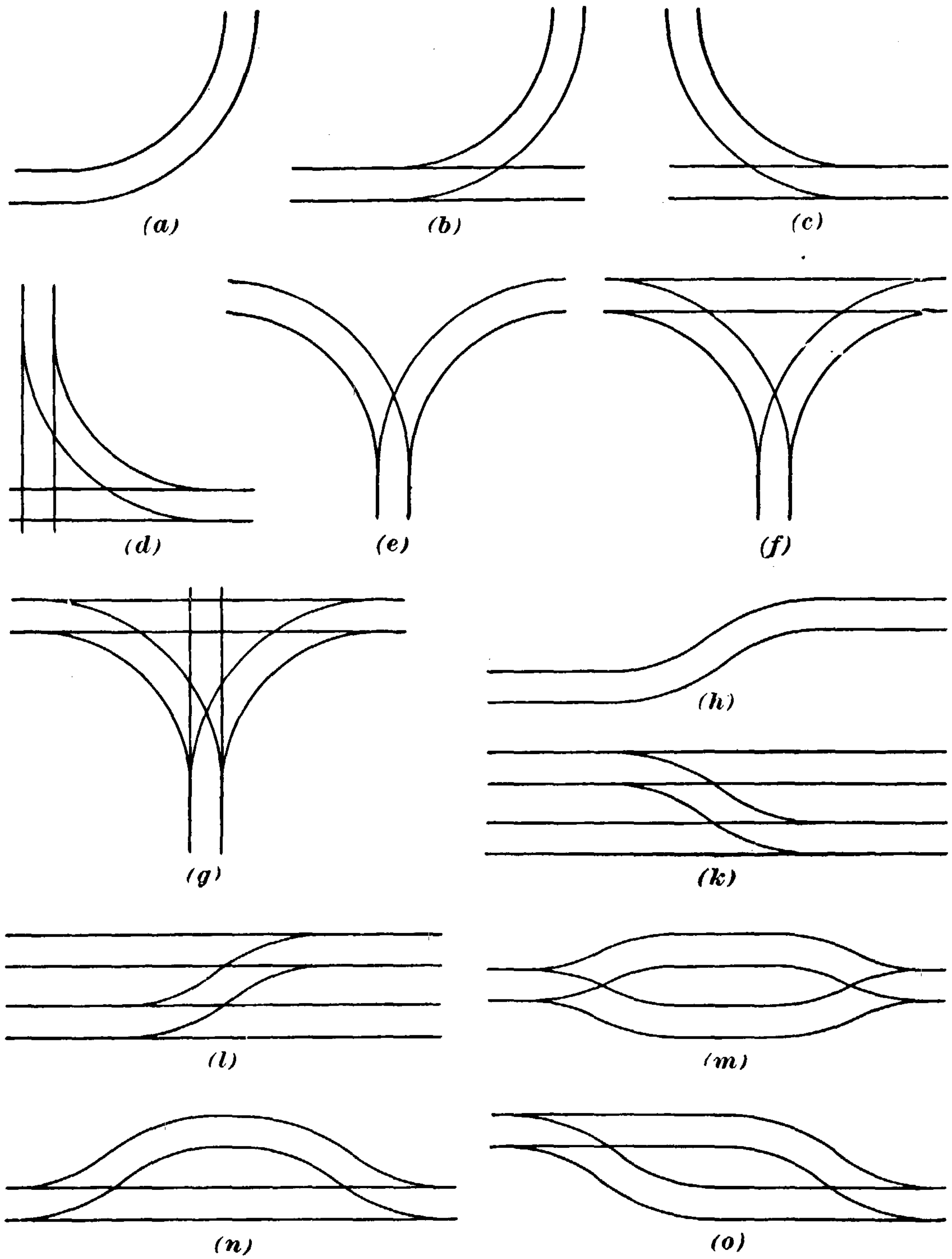

FIG. 52.

cross over from one track to the other. These are very convenient devices to place here and there in a main line to turn cars back, either when they are crippled or to get them on their time after a long delay. When it is practicable, a cross-over should be put in so that its switch points will lay in the direction of travel on the two tracks. Fig. 52 (*m*) shows a *diamond turnout;* Fig. 52 (*n*), an ordinary *siding*, and Fig. 52 (*o*) what is called a *thrown-over turnout*, seen very often in temporary work, where it is of the nature of a temporary cross-over to avoid a gang of workmen.

52. Guard Rails.—Guard rails are rails provided with a protecting flange to prevent a car from climbing the rail on a curve. Guard rails can be solid or made up. Girder guard rails are, as a rule, solid; **T** rails are made up. Fig. 53 shows a section of a girder guard rail and Fig. 54 shows a section of **T** rail provided with a guard. The **T** rail need only be provided with a regular guard where it is used in a paved street. In country work, the steam-road practice of laying a second line of **T** rail next to the inside-track rail is adopted. This practice is also adopted, as a rule, on bridges, where the guard rail is, however, laid beside both track rails. The best authorities are inclined to the belief that a guard rail on the inside, or short rail, of a curve affords ample protection, but it is common to see a guard on both the inside and outside rails of short curves. At any rate, it is not safe to rely on the flange of the outer wheel alone to keep the car on the track, for car wheels in street-railway service, on account of the heavy weight attached to the axle and also on account of the nature of the special work that they have to jolt over at times, are addicted to the trouble of broken or chipped flanges. A wheel with such a defect in the flange is almost certain to climb the rail if that wheel is on the front end of the car as a leader. As in the case of ordinary grooved rail, a great deal of judgment must be used to select a groove that is adapted to the flanges of the wheels used.

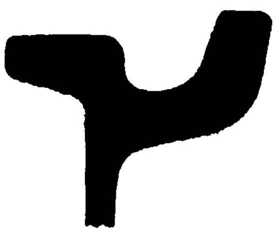

FIG. 53.

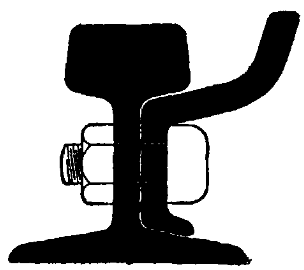

FIG. 54.

EXAMPLES OF STREET-RAILWAY TRACK CONSTRUCTION.

53. Fig. 55 shows a cross-section of a very substantial roadbed used in the State of New York. The figure shows a single track only, although the road is double track. A trench 23 inches deep is opened up 18 feet wide. This is well rolled and filled to a depth of 8 inches with 2-inch broken stone, soft spots in the rolled surface being dug out and also filled with the stone or other solid material. The stone is rolled until it is firm at a depth of 8 inches. On this ballast are laid the ties, 6 in. × 7 in. × 7 ft. 6 in., a little less than 2 feet between centers, except at the joints,

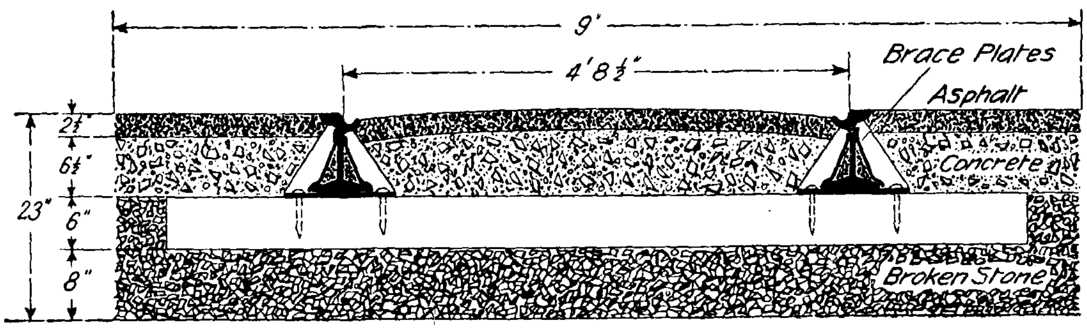

FIG. 55.

which are supported by three ties about 15 inches between centers; 60-foot rails are then laid on the ties, ends butted and joints staggered. Before jointing, the ends of the rails and the joint plates are well cleaned to take the bonds. The rails are then coupled, the plates bolted tight, brace plates installed every 3 or 4 feet, ties lined up and spiked to the rail. The track is then lined and surfaced and the space between the ties filled with broken stone, well tamped to the top of the tie. The rail is then finally lined, the joints secured, and the broken stone or concrete brought up to the paving.

54. Fig. 56 is an example of roadbed construction on a weak subsoil, and Fig. 57 shows a very novel method of paving to a **T** rail. In the roadbed construction in Fig. 56, a trench 36 inches deep and the width of the tracks is dug; the trench, as shown by the figure, is filled to a depth of 29 inches with successive layers of 12-inch hard earth and rock well beaten down; 10-inch earth, pebbles, clay, sand, and rocks, well tamped; 7-inch new concrete; and 6 in. × 8 in. × 8 ft. hard pine ties, previously boiled in asphalt, are laid on the concrete to take 80-pound **T** rails. At joints the ties are supported on steel plates bolted to the concrete. The track is 3 feet 6 inches gauge and 12 feet between the centers. The paving is flush with the head of the rail on the outside.

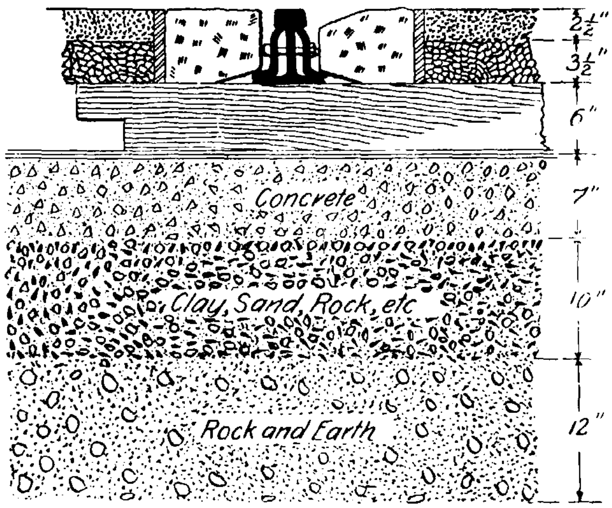

FIG. 56.

On the inside of the rail it is brought up, except at joints, to the lip of an **L** plate supported, as shown in Fig. 57, by the foot of the track rail and tied by a bolt that passes through it, the web of the rail, and the body of a **Y** filler, which acts as a groove for carriage wheels. At the joints where the **L** rail is discontinued, the groove is formed by stone blocks set in a steel frame. This method of construction, while somewhat bold, has given great satisfaction.

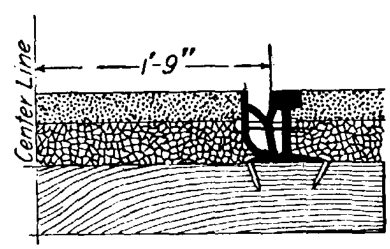

FIG. 57.

55. Fig. 58 shows a track construction where the rails are supported on concrete stringers *A*. The rails are connected together by steel cross-ties. This figure shows the method of paving brick up to a **T** rail, and Fig. 59 shows the method of bringing up the asphalt. The rail is a 60-pound **T**, 6 inches high, in 60-foot lengths. On straight track, it is laid on 24-pound steel ties, 3 feet between centers,

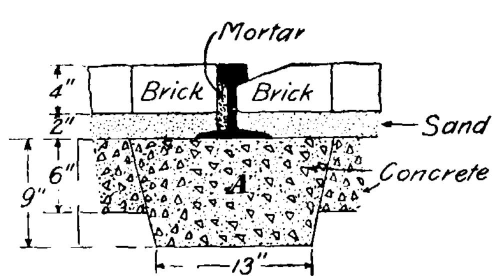

FIG. 58.

and on curves and special work, on 6 in. × 8 in. × 6 ft. 6 in. oak ties. All joints are broken or staggered and are carried on steel plates. In the construction shown in Fig. 59, the concrete comes above the foot of the rail; in order to get it well tamped under the rail and to avoid troubles incident to shrinkage on setting, the concrete was mixed with as little water as possible. The construction work, in brief, was as follows: After the old track was removed and the street dug out and rolled to grade, the new work was put in place, assembled, surfaced, lined, and gauged while temporarily supported on wooden blocks. The trenches for the concrete beams or stringers were then dug and the wooden formers placed in position. The 6-inch paving concrete was next laid, allowed to set for a day, and the formers removed to make way for the stringer, which was then installed. The concrete in the stringer was allowed to set for a week before a car was permitted to go over it. As the work was done in extremely hot weather and as the variation in length of the exposed rail was about 10 inches per 1,000 feet between night and day, the disastrous effects of this great expansion and contraction had to be prevented. This was done as follows: In the brick construction, as fast as the paving concrete was laid, the sand to be used as a paving bed was heaped over the rail and wet down; this was supplemented by turning **V**-shaped wooden troughs upside down over the whole.

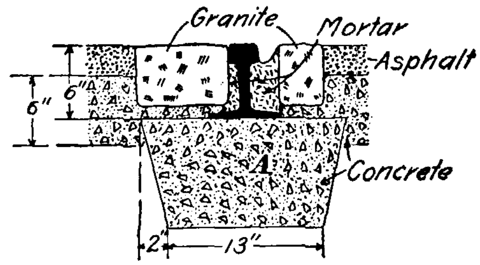

FIG. 59.

56. Fig. 60 shows a section of track construction in Detroit. It employs the best features of the two systems that formerly existed there and includes the concrete beam and the steel cross-tie (3-inch angle bars), used more as a tie-rod for keeping the rails to gauge than as a solid resting place for the rails. The concrete-beam work ordinarily goes to a depth of only 6 inches, but in soft spots it goes to a depth of 2 feet, if necessary. The concrete used in the beam is composed of 1 part Portland cement, 4 parts Louisville cement, 8 parts sand, and 16 parts broken stone, laid to a depth of 6 inches in a trench and brought up 1½ inches above the bottom of the ties.

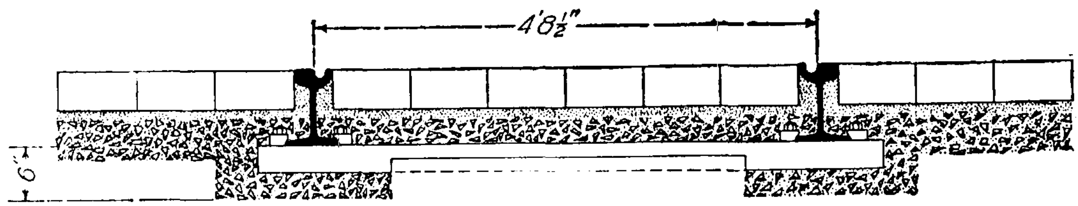

FIG. 60.

57. Fig. 61 is a section through a roadbed construction used in Chicago. One of the standard constructions is as follows: The street is excavated to grade to receive a layer of broken stone rolled to a depth of 6 inches; on this stone, 2 feet between centers, are laid the white oak ties 5 in. × 8 in. × 7 ft.; the rails, 85-pound girder section, are spiked to the ties and the space between ties is filled with broken stone or slag, which is well tamped to surface, and the rail lined. After the track is lined and surfaced, the stone is brought above the surface of the ties, where is placed a 1-inch

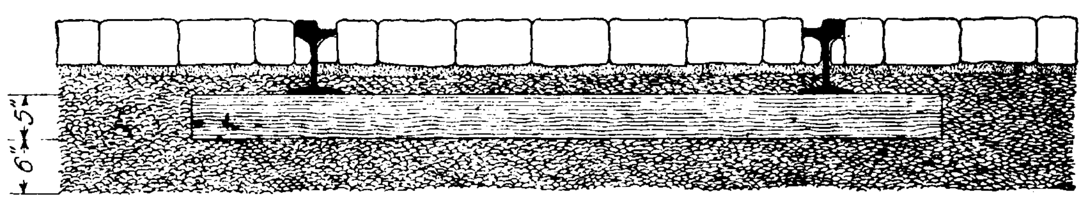

FIG. 61.

layer of sand on which the paving blocks rest. The depth of the roadbed has lately been increased from 6 to 8 inches; this, together with the fact that 60-foot rails and cast-welded joints have been adopted, will go a long way towards lessening the trouble from poor joints. There are over 100,000 of these joints on a single system, and all the roads have their own cast-welding outfits. So much faith is there in the conductivity of the cast-welded joint that in some instances the use of bond wires has been discarded. The wisdom of this practice, however, is very doubtful. Unless the several lines of rail are well cross-bonded, the development of a single bad joint might materially affect the voltage at some remote part of the system.

58. Construction in Soft Subsoil.—Fig. 62 shows a style of track construction used in New Orleans. This city is very little above sea level, and most of the year the river is above the city. These facts, together with the fact that the subsoil is thoroughly permeated with holes made by the crawfish, make the city a floating land in the sense that wherever a hole is dug it immediately fills with water. It is not hard to conceive, then, how a roadbed constructed along the usual lines would soon give trouble. Several of the long lines in the city are built on neutral ground between two driveways, so that they are not subjected to the wear and tear of wagon traffic. This location of the

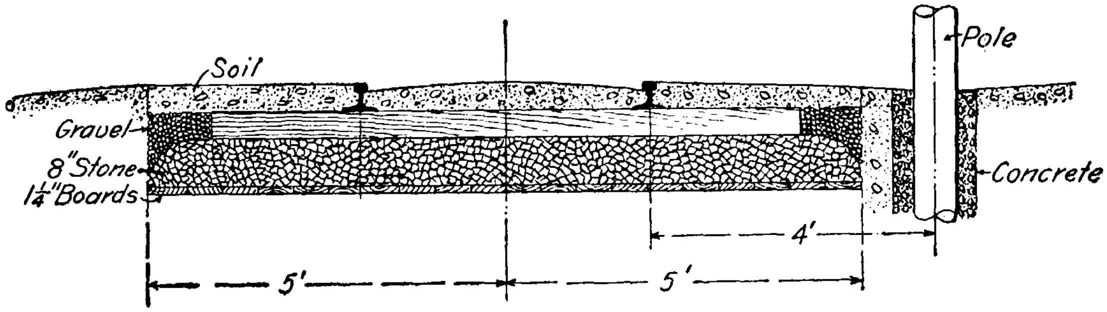

FIG. 62.

tracks admits of the use of a **T** rail. Fig. 62 shows a section of the **T**-rail construction. The first step is to dig two trenches, one for each track, about 2 feet deep and 10 feet wide. The space between tracks and between the tracks and the roadways is all grass-grown, and as there is no traffic on it, no roadbed is needed. On the bottoms of the leveled trenches are laid lengthways $1\frac{1}{4}$-inch yellow-pine boards. This acts as the foundation for a layer of $1\frac{1}{2}$-inch broken stone, on which the 6 in. × 8 in. × 8 ft. creosoted yellow-pine ties rest, 2 feet between centers. The space between the ties is filled partly with broken stone and partly with gravel that goes to the top of the ties. On top of the gravel is put a layer of soil in which grass is sown, so that a few months after the work is done the whole neutral ground is grass-grown—a feature that almost entirely does away with the clouds of dust ordinarily raised by a car in course of rapid transit. The plank construction on the bottom of the roadbed prevents the tendency of the track to sink into the soil and cause undulations in the surface line of the rail. The use of the **T** rail does not introduce complications at crossings, some of which are asphalt and others stone, because all wagon traffic being across the rail, no provision need be made for carriage wheels. At asphalt crossings the paving is brought right up to the head of the rail on both sides and the car-wheel flanges are allowed to cut their own flange ways. At stone-paved crossings the stone is flush with the rail head on the outside and on the inside a narrow space is left as a flange way. The rail used in this particular construction is $5\frac{3}{4}$ inches high, weighs 100 pounds to the yard, and is in 60-foot lengths. The joints are broken and are bonded with a No. 0000 B. & S. concealed bond.

59. Construction for Conduit Road.—There are no overhead wires allowed in the city of New York, so that all track work must be made to conform to the use of a slot to pass a cable grip or a trolley plow. The Third Avenue

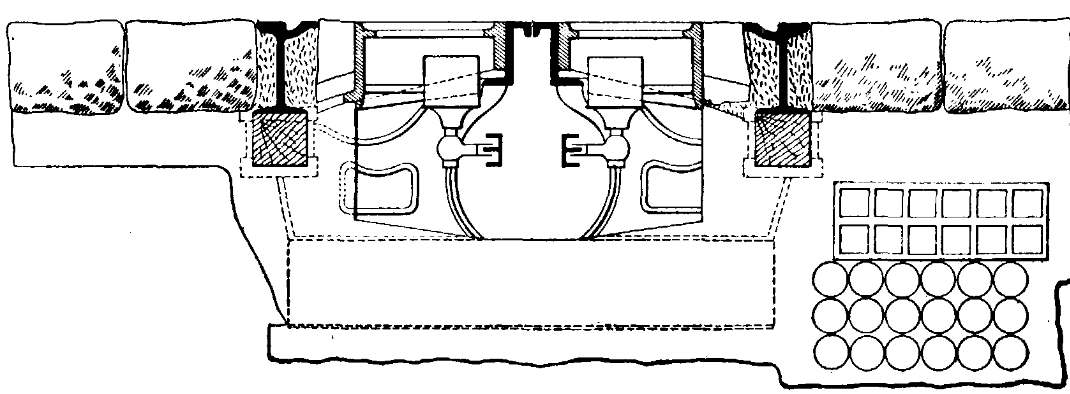

FIG. 63.

Railway affords an example of recent track work for a conduit road. The first step towards installing a conduit is to dig a trench about 3 feet deep and the width of the roadbed. The trench is rolled to grade and a 4-inch layer of concrete put on its bottom. Fig. 63 is a section through the construction in question. The 4-inch layer of concrete forms a surface on which to aline the ironwork, all of which is assembled before the main body of concrete is installed. The track rails and slot rails are supported on iron yokes spaced 3 feet apart and made up in three pieces, which is a new feature in such work. The three members are a steel **I** beam *A* and two cast-iron side pieces *B* (see *A* and *B*, Fig. 64) weighing about 125 pounds each. The yokes rest on the 4-inch concrete bottom, and the space between the yokes, the center of which space is the conduit proper, is filled with concrete that must be put in after the iron is in place,

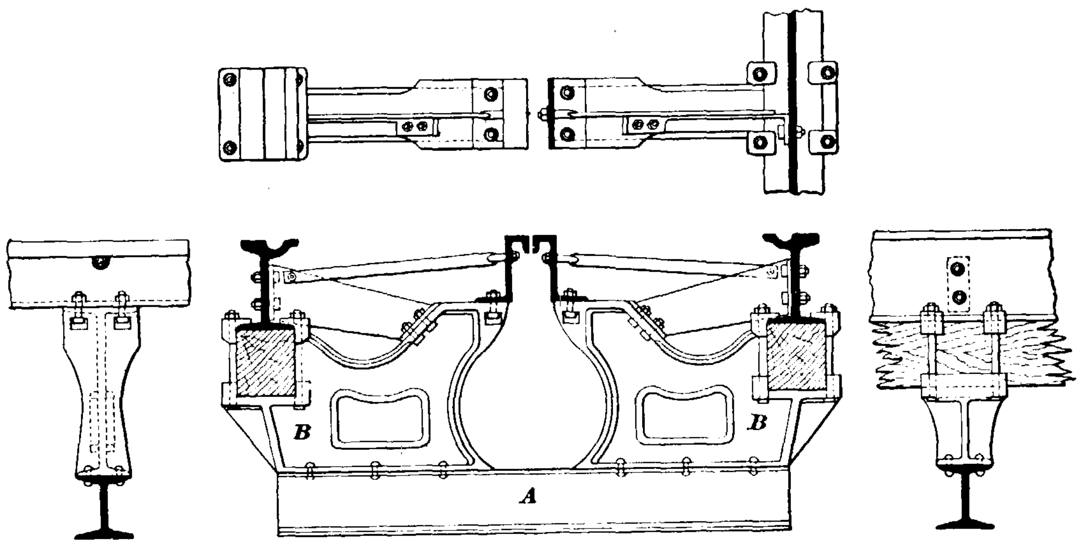

FIG. 64.

because the throat of the yoke dictates the general shape of the concrete part of the conduit. In order to shape the walls between the yokes, iron linings are used to support the concrete until it has set. These linings are made so that they can be freely drawn through the slot either way, and they are forced into position by means of a folding form operated by a lever. Fig. 64 gives a section through a plane that shows one of the yokes. The track rails are 9-inch grooved girders 107 pounds to the yard, in 60-foot lengths, laid on pine stringers. This stringer construction is a new feature in this class of work and is in accordance with the idea held by many engineers that a rigid support for the rails does not afford an easy riding track.

THIRD-RAIL CONSTRUCTION.

60. General Remarks.—The supply of current to cars has already been described in a general way in *Electric Railways*, Part 1. This method is coming largely into favor where the traffic is heavy. It has already been adopted on a number of elevated roads in New York, Brooklyn, Chicago, etc. It has also proved much superior to the overhead trolley for cross-country lines. It seems to be the only system adapted to the supply of heavy electric currents at normal voltages to meet the requirements of steam-road traffic conditions. In high-speed work, it is absolutely necessary to employ a rigid conductor that will not sag or sway under the influence of the moving contact. A good heavy steel rail seems to fulfil this condition to perfection. This rail, which gives the name to the system, is laid either between the two track rails or to one side and above one of them. The center-rail construction is safer in so far that it offers less opportunity for a person to step on it from the track rail, but this feature should not be relied on for safety. On the other hand, the side-rail construction is free from all liability to short-circuits due to a motor or brake rod or other part of the equipment coming loose in service and falling across the track rail and the third rail. The third rail is of much more assistance as a conductor than the ordinary trolley wire, because it has a large cross-section, and thus cuts down the amount of copper required for feed wires.

61. Examples of Third-Rail Construction.—The construction used on the Nantasket Beach road and described briefly in *Electric Railways*, Part 1, was one of the earliest third-rail systems installed in the United States. In this case, a third rail of special shape was used, but in the later roads it is nearly always of the ordinary **T** shape. In some cases these rails are insulated by supporting them on creosoted wooden blocks; in other cases they are supported on insulators made of "reconstructed granite," porcelain, or other insulating material. In Brooklyn, the third rail is outside of and above the track rail; sometimes on one side of the track and sometimes on the other, according to the surroundings. Each motor car carries four contact shoes, one on each corner of the car, and two of these shoes are always in a position to be active. The third rail is made up of all kinds and weights of old T rails, with the result that the joints are in some cases very uneven and have given a great deal of trouble by knocking off the contact shoes. The rails are held together by fish-plates and are bonded similar to the track rails. At branches, turnouts, cross-overs, sidings, etc., where it is necessary to break the line of the third rail, end pieces called **nosings** are fastened between the ends of the third rails and act to guide the shoes on the rail again. These nosings, which are of cast iron, are wider than the rail itself. They are bent down considerably on the ends and are renewable. They are found to give better service than bending the rail itself down to form a nosing. Where the line of the rail is broken in this way, the circuit is made continuous by means of a copper connecting cable. The third-rail line is supported at close and regular intervals on strong insulators made of reconstructed granite. The contact, or collecting, shoes are fastened to that part of the truck that is deflected least, and hence varies least in height when the load on the car changes. The shoe beam must, therefore, be hung from a point that is not responsive to the action of the main-truck springs. On account of this comparatively rigid suspension of the shoe beam, with its contact shoes, it is absolutely essential that the surface line of the third rail be true and level and that the tops of the rails at joints be exactly flush; if they are not, as experience has proved, there will be no end of trouble from losing contact shoes. As a factor of safety, it is well to make the slotted links, by means of which the steel shoes are hung from the steel rack, of gray cast iron, so that in case the passage of the shoe along the rail becomes obstructed for any reason, the links will give away and the rack and beam will be spared.

62. Fig. 65 shows the style of contact shoe used on the Albany and Hudson third-rail road. It will be noticed

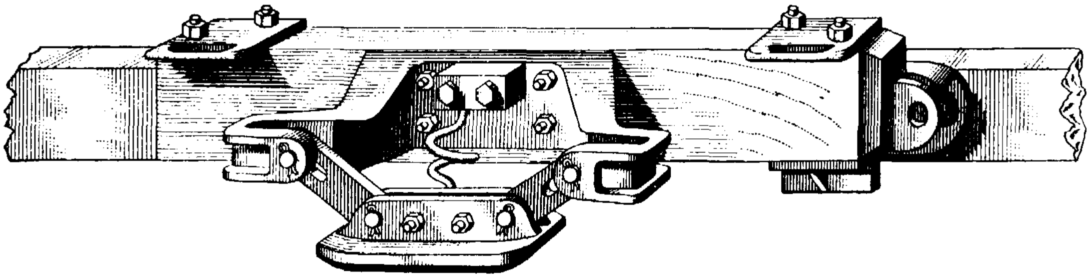

FIG. 65.

that it is very similar in general design to that described in *Electric Railways*, Part 1, as used on the Nantasket Beach road. Fig. 66 shows the style of support used for the third rail on the Albany and Hudson road. Every fifth tie is extended to one side so as to take the third-rail support, which consists of a wooden block *A*, to which is attached the malleable cast-iron top *B*. The third rail is held by keys under the ears *c*, *c*. This road uses an 80-pound **T** rail for the third-rail conductor.

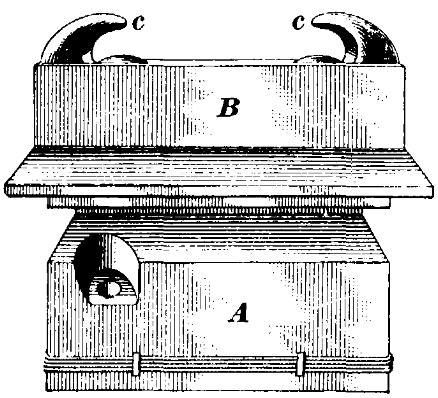

FIG. 66.

63. Snow and Ice on Third Rail.—Snow and ice often cause a great deal of annoyance in connection with the operation of third-rail roads. There are times when the third rail gets so thoroughly coated or glazed with a thin layer of ice that the trains have been unable to run at all. The ice is such a poor conductor that the current will not go through it as thin as it is, and yet it is so smooth and hard that no mechanical device outside of a milling machine will effectively remove it from the surface of the rail. Several devices have been tried for keeping the rail clear of ice; among the most effective may be mentioned a free use of oil to keep the ice from forming and a free use of brine to remove the ice if it is already there. Both of these schemes have been only partially successful, but have done good work in the absence of better means. It has been the practice to apply the oil by means of an ordinary swab in the hands of men placed at intervals along the line; the salt water can be squirted on to the rail by means of a small rubber hose, leading from a tank placed on the rear end of a train or car especially adapted to do the work. The oil cannot be so applied, because the problem of getting the liquid, whatever it may be, on the rail and not in the street below has given a great deal of trouble.

64. Third-Rail Precautions.—The ordinary third rail cannot, of course, be used for surface roads in cities. Its use for city work is, therefore, confined to elevated roads. In densely populated parts, the third rail should be split up into a number of sections, and the feeders supplying these sections should be provided with switches, so that in case of fire, either on a car or in nearby buildings, the current may be cut off. In case of fire, the live third rail is very often a source of hindrance to the firemen in the performance of their duties, and in some cases is even a source of danger. When a fire, caused by some abnormal condition of the circuit, occurs on a motor car, the only way to break the current, if the feeder switch cannot be reached and the circuit-breaker is out of order, is to lift the contact shoes from the rail, and this is not an easy thing to do, unless there are special means provided for the purpose. Every motor car should be provided with a pair of wooden paddles with handles about 3 feet long. To cut off the current, it is only necessary to shove one of these paddles in between the third rail and each of the two active contact shoes.