ELECTRIC RAILWAYS.

(PART 6.)

CAR APPLIANCES.

1. Trunk Wiring.—Fig. 1 indicates the trunk wiring of an ordinary car and shows those devices, outside of the motors and controllers, that are necessary for the operation

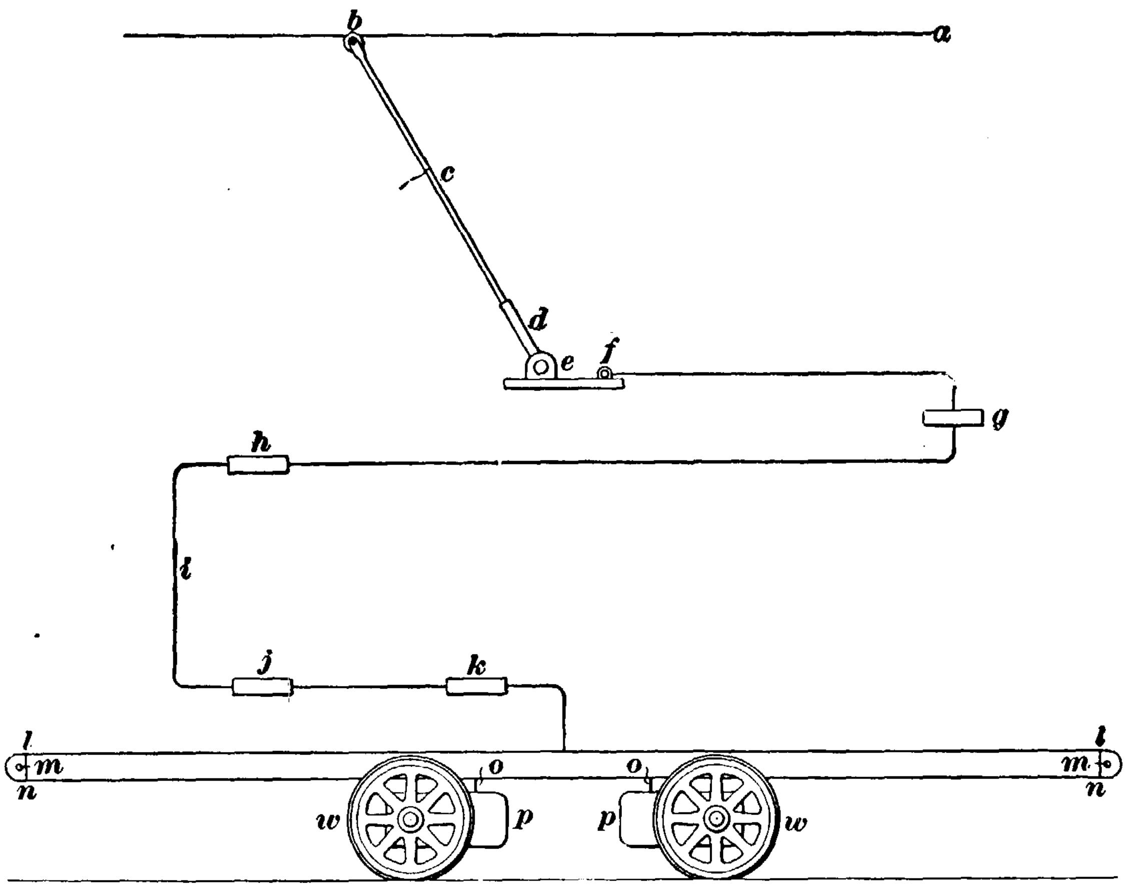

FIG. 1.

of the car. The appliances used for heating and lighting are not indicated. The trolley wheel *b* is held in a *harp* that is mounted on one end of the trolley pole *c*. The other end of the pole fits into the *socket d* on the *trolley base e.* One end of the trunk wiring attaches to the trolley base at *f* and after passing through the two hood switches *g*, *h* and the fuse box *j*, splices on to the wire *l l* running to the trolley posts in the two controllers. In some cases, the current also passes through the lightning arrester *k*, though usually the arrester is simply tapped on to the main trolley wire.

TROLLEY POLE AND FITTINGS.

2. The Pole. — The *pole* proper, which is from 12 to 15 feet long, is about 1½ inches in diameter at the large end, and holds this diameter for about 2 feet of its length, when it begins to taper and gradually draws down to a diameter of 1 inch. Most poles are steel, hard drawn by a special patented process, and offer great resistance to bending. A slight bend in a pole is generally straightened by using a post with a hole in it as a vise and bending by hand; but severe bends should be taken out by sledging cold. A pole should not be heated to straighten it, as the character of the

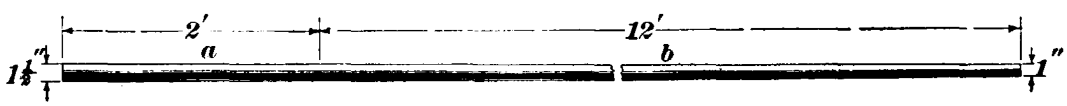

FIG. 2.

steel is such that the part heated becomes soft and easily bent. The poles generally used cost from $1.50 to $2.00, according to the length and quality. Fig. 2 gives an idea of the straight and tapered part of a standard pole.

3. The Ferrule.—As a rule, each pole is provided with a *ferrule*, which is designed to receive the trolley rope, and which consists of a brass or malleable-iron ring with an eye in it to take one end of the rope. It is secured to the small end of the trolley pole,

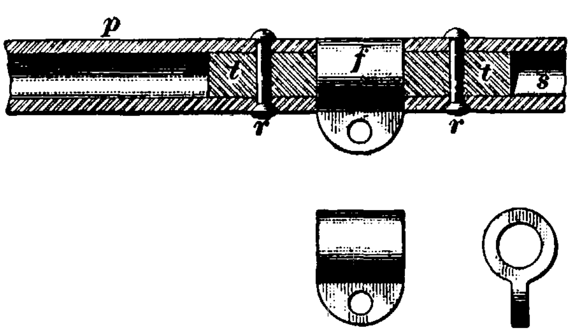

FIG. 3.

as shown in Fig. 3, where p is one end of the pole, f is the ferrule, and s is one end of the harp stem; t t is a pin passing into the pole and stem through the ferrule. This pin fits the ferrule loosely, so that the latter may be free to turn when the pole is swung around, but it is forced into the pole and harp stem and is riveted by means of rivets r, r. A ferrule is not used on all roads, its place being taken by an eye cast in a projection on the harp itself, as shown at e, in Fig. 4. In either case, the eyehole should be well rounded out to avoid cutting the rope, a thing that happens very often and causes much inconvenience. Fig. 4 also shows the manner of attaching the harp directly to the pole. In this figure, b is the harp; p, the end of the pole; and t, t, the rivets by which the two are fastened to the connecting pin.

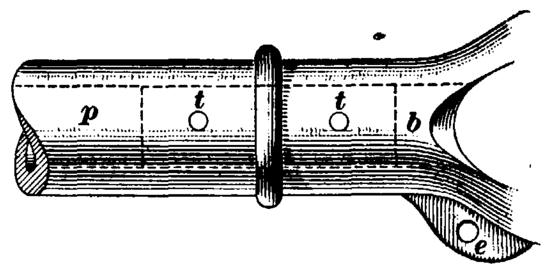

FIG. 4.

4. The **harp** is the name given to the fork that holds the trolley wheel and its axle; it also holds two contact springs s, s, Fig. 5. In this figure, b is the harp proper; a, the axle; s, s, the two springs on either side of the harp; and c, c, two cotter pins that pass through two holes drilled into the ends of the axle and serve to keep the axle in place. It has been the custom to make trolley harps of brass, but malleable iron is fast replacing it, because it is cheaper and stronger and offers less temptation to thieves. The main points that govern the selection of a harp are narrowness and smoothness; all edges should be nicely rounded off

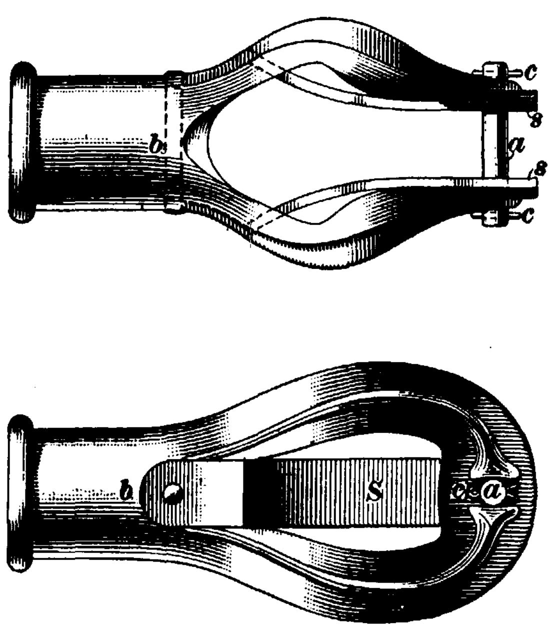
FIG. 5.

to avoid catching in the line work when the trolley wheel flies off the wire. The selection of a good harp means a great saving in poles, ropes, and overhead work.

5. The Wheel.—The trolley wheel is a device on which much experimenting has been done to determine the best shape of wheel and the best composition of metal consistent with long life of the wheel and trolley wire. Some wheels wear out sooner than others and some are harder on the trolley wire than others. A wheel that is too soft will wear out very soon; on the other hand, a wheel that is too hard or that has a poorly shaped groove will scrape the trolley wire at curves and turnouts. Almost all roads go through a certain amount of experimenting to decide what shape and

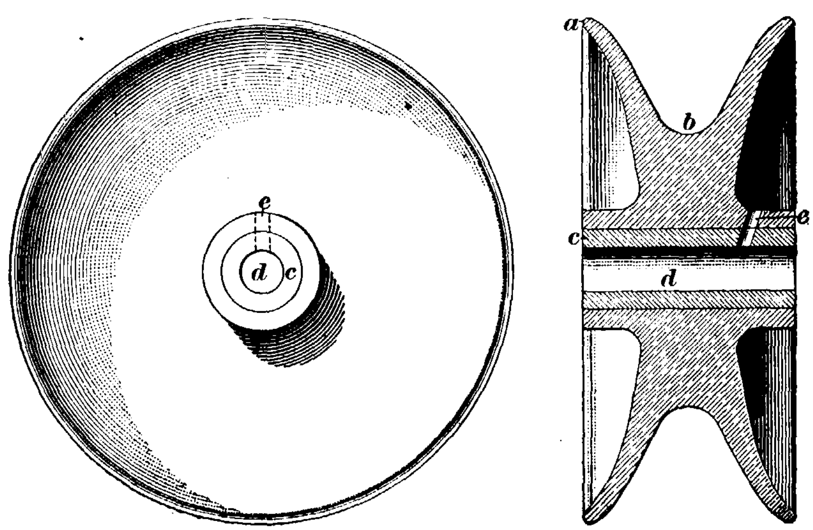

FIG. 6.

metal are best adapted to the overhead construction. A good lesson can be learned from a careful observation of worn-out wheels; some wheels wear out most in one place and some in another; the same make and shape of wheel will wear differently on different branches of the same road. If both flanges of the wheel persist in getting sharp, it indicates that the groove is too deep or too narrow, or both. If the groove wears down to one side, the indications are that the pole is in crooked or that the harp is crooked or that the trolley wire is out of center. Too much stress cannot be laid on the importance of getting the pole so adjusted that when it is in its normal position, the trolley wire rests on the bottom of the groove and runs parallel to the flanges. Fig. 6 shows a trolley wheel; *a* is the flange; *b*, the groove; *c*, the bushing or bearing; *d*, the hole through which the axle passes; and *e*, the hole for oiling. The bushing, or bearing, is a brass spiral sleeve filled with graphite, and can be forced in or out of a wheel when wear makes it necessary to do so. The bushing is a very particular part of a wheel and should be well made; to keep a bushing in good order, it should be well oiled every fifteen or twenty miles that the car makes; for when it is taken into consideration that a trolley wheel turns around about five thousand times every time that the car runs a mile and that cars make several miles an hour, the importance of a perfect bearing is apparent. On roads that make any pretension to looking after their trolley wheels, a platform is built that overhangs the car roof, so that the wheel may be oiled. Fig. 7 indicates the kind of platform referred to. When oiling a wheel, a piece of waste should be held under it to prevent the excess of oil falling on the roof of the car, where in course of time it makes a mess. When a wheel is allowed to run dry, the hole in the bushing soon wears to an oblong shape, allowing the wheel to vibrate and emit a chattering noise. The same noise may be caused by a wheel having flat spots in the groove. These flat spots may be due to the wheels sliding along for want of oil instead of turning; in other cases, they may be due to some imperfection or they may be due to soft spots in the metal of which the wheel is made. In any case, the wheel should not be run, but should be taken out, and if there is any stock left in it turned down to be used again.

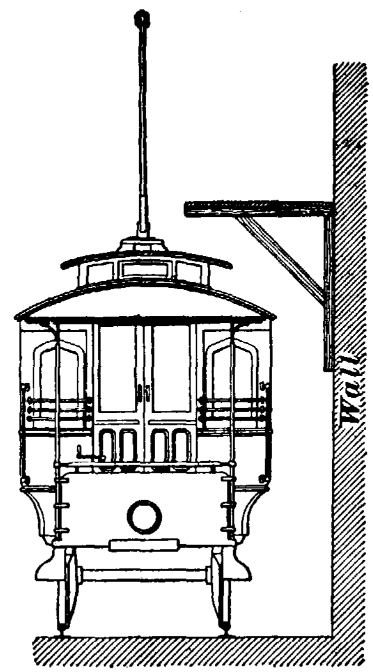

FIG. 7.

TROLLEY STANDS.

6. General Description.—The pole fits into and is held by a device called the **trolley stand,** which gives the pole freedom of motion in two directions: up and down, to enable the pole to adjust itself to stretches of wire varying in height above the ground, and sidewise, so that the pole may be swung around when the direction of motion of the car is changed and also that it can follow the wire freely in going around curves. The trolley stand has two members: the upper member, which holds the pole and is free to turn around the lower member in a horizontal plane, and the lower member, called the base, which is screwed to the board or bridge and acts as a center around which the upper member may turn; this lower member also receives the wire that leads the current from the trolley stand to the controlling devices. The upper member includes the *socket*, the *spring*, and the devices for adjusting the tension on the spring.

7. The Nuttall Trolley Stand.—Figs. 8 and 9 show one form of Nuttall stand. *G* is the socket proper and *f*, *f* two wings forming part of the socket casting provided to

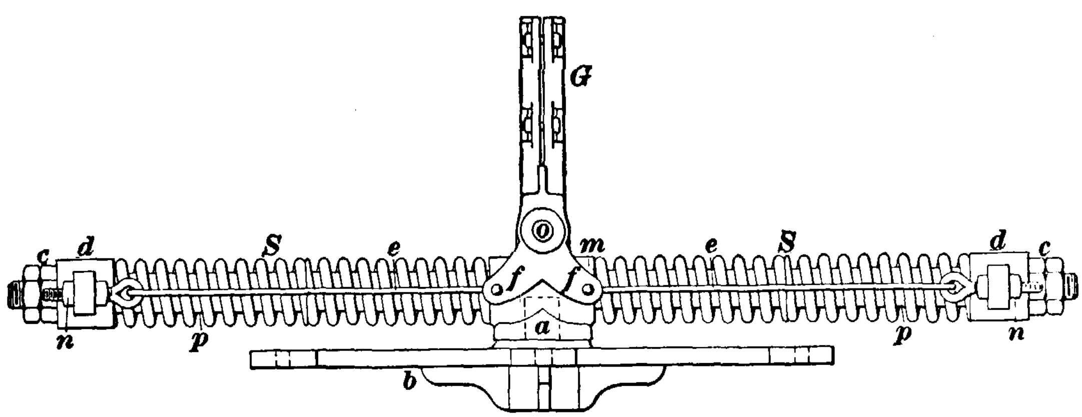

FIG. 8.

receive one end of adjusting rods *e*, *e*, the other ends of which pass through cup castings *d*, *d* to receive adjusting nuts *n*, *n*. On this form of trolley stand the pole may either be rocked over independently or it can be swung around with the upper member *m*. Casting *m* also receives the two guide rods *p*, *p*, over which work springs *S*, *S*. When the pole is pulled one way or the other, one pair of tension rods (only one of each pair is shown in the figure) pulls on one

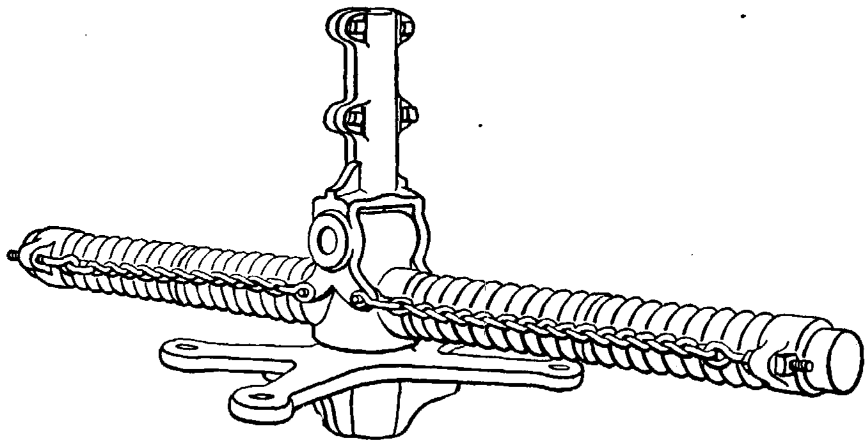

FIG. 9.

compression cup, compresses one of the springs, and produces the desired pressure of the wheel against the trolley wire. To increase the force with which the wheel is pressed against the trolley wire, tighten the nuts *c*, *c*; this will cause some slack in rods *e*, *e*, so that the nuts *n*, *n* also must be tightened. To render springs *S* entirely inactive, remove the

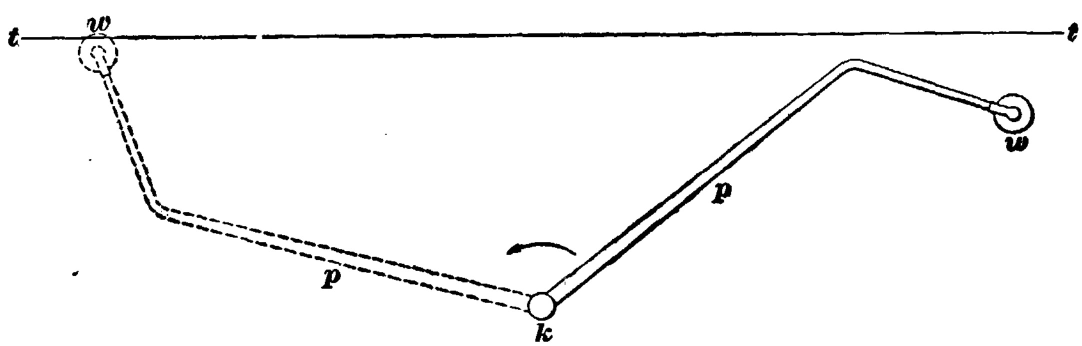

FIG. 10.

nuts *n*, *n* altogether. In the Nuttall trolley, it is possible either to swing the trolley around or to let it stand straight up and rock it over in the opposite direction. All trolley stands do not admit of this, but it is a good feature, because in case a pole is bent, as shown in Fig. 10, rocking the pole over does away with the disadvantages of the bend, whereas swinging the pole will do no good at all. Sometimes, instead of the rods *e*, *e*, chains are used, as shown in Fig. 9.

8. The T. H. Trolley Stand.—Figs. 11 and 12 show a form of trolley stand that was formerly much used. Fig. 12 is a perspective view of the upper member of the stand. On bending the pole to the left, rocker *R* winds up the straps attached to the spring frames and pulls out the battery of springs *S*. To increase the tension, nut *n* must be tightened. It can be seen that with this style of base the trolley pole cannot be rocked over, but must be swung

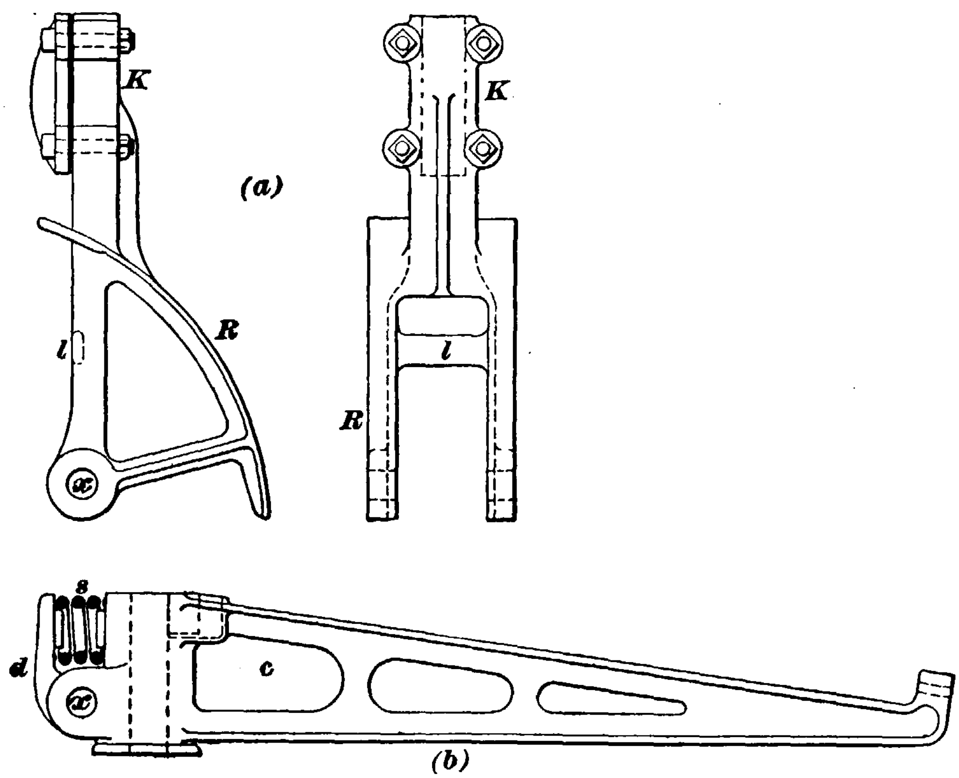

FIG. 11.

around with the upper member. In Fig. 11 (*b*), a spring *s* may be seen on the main casting *c*. There is a projection on one side of the main casting, and this projection goes into one end of the spring; an iron dog *d* that moves around the same center as the rocker casting *R* has a slight projection that goes into the other end of spring *s*. In case the trolley rope breaks or for any other reason the pole flies up, rib *l* of casting *R* compresses spring *s* and relieves the trolley stand of the great shock it would otherwise receive. The variety of trolley bases in use is very large, but they all contain about the same essential features.

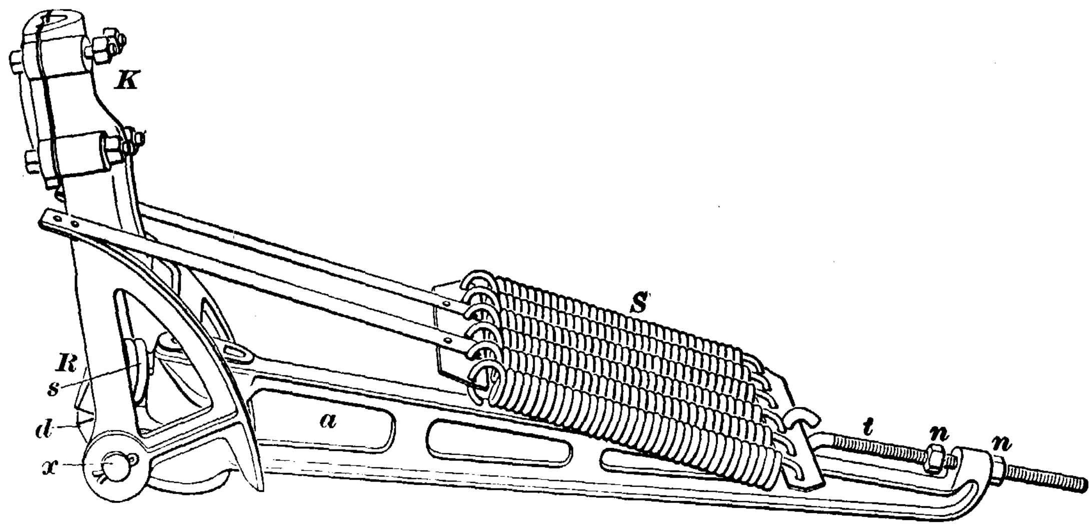

FIG. 12.

9. Pressure Between Wheel and Wire.—The pressure with which the wheel presses against the trolley wire varies from 12 to 20 pounds, according to local conditions and to the speed at which the car is to be run. If the pressure is too light, the pole will be continually jumping off the wire at every kink or turn; if the pressure is too great, it causes an unnecessary wear of the trolley wire, wheel, and axle and also makes it much more difficult to get the wheel back on the wire after it has jumped off. Under ordinary conditions, the pole should make an angle of about 45° with the roof, or deck, of the car, and a pressure of about 15 pounds between the wheel and the wire will usually give good results.

CANOPY SWITCHES.

10. General Description.—The canopy switch, also called the hood switch, bonnet switch, overhead switch, or main-motor switch, is a device that is placed just above the motorman's head on the under side of the bonnet. It is preferably placed a little in front of the motorman's position, so that he can look up and see it without turning his head around. The object of this switch is to provide a certain and simple means of cutting off the main-motor current, in case anything should happen to one of the controllers to make that device useless for throwing off the power. Sometimes a controller becomes grounded or short-circuited, and the consequent flow of current through it is so great that the controller cannot break it; again, sometimes the trouble with the controller or some other device is such that it is very convenient to put the controller on the first or second notch and to start, run, and stop the car by means of the canopy switch. This switch is also used to entirely cut the wiring and all the devices out of communication with the trolley wire when it is desired to inspect or work on any of the controlling devices. A motorman should never try to adjust a controller finger or to replace a broken motor brush without first throwing the canopy switch handle to the off-position.

11. Westinghouse Canopy Switch.—Fig. 13 shows the general appearance of the Westinghouse switch. The switch fixtures are mounted on a wooden base and over the whole is fitted the iron cover provided with four legs, by means of

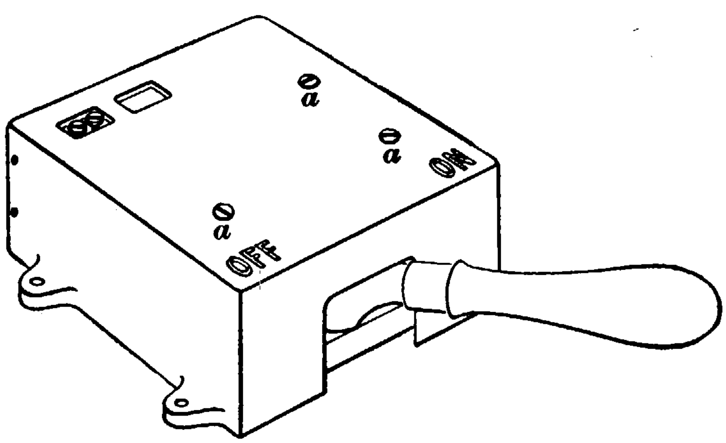

FIG. 13.

which the switch can be fastened to a wooden baseboard screwed to the under side of the bonnet. The iron cover can be taken off by taking out the three screws *a*, *a*, *a*, exposing the inside to view. These switches are sometimes called upon to break currents from 200 to 300 amperes, and some special provision must be made for doing this without too much arcing. In the Westinghouse canopy switch this is accomplished by having the switch blade break the current in two places at once, the two breaks being separated from each other. Figs. 14 and 15 show the construction of the Westinghouse switch blade and the path of the current when the switch is closed. In Fig. 14, *h* is a

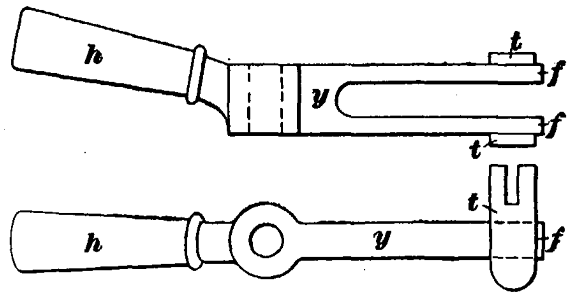

FIG. 14.

wooden or rubber handle; *y* is an open-shaped piece of brass terminating in legs *f*, *f* that receive the contact tips *t*, *t*. In Fig. 15, *e*+ is the wire leading into the switch, *e*— the wire leading out of it; *a* and *c* are spring blades set into brass lugs *l*, *l*, separated from each other by the block of insulating material *d*. When the switch is closed, as shown in this figure, contact tips *t*, *t* press into blades *a*, *c*, and the path of the current through the switch is *e*+ –*l*–*a*–*b*–*c*–*l*–*e*—.

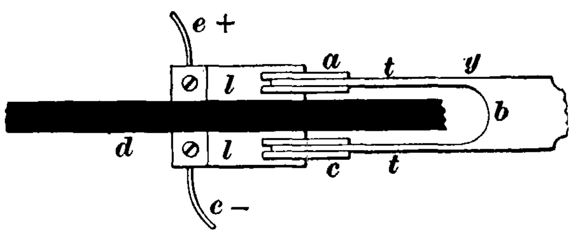

FIG. 15.

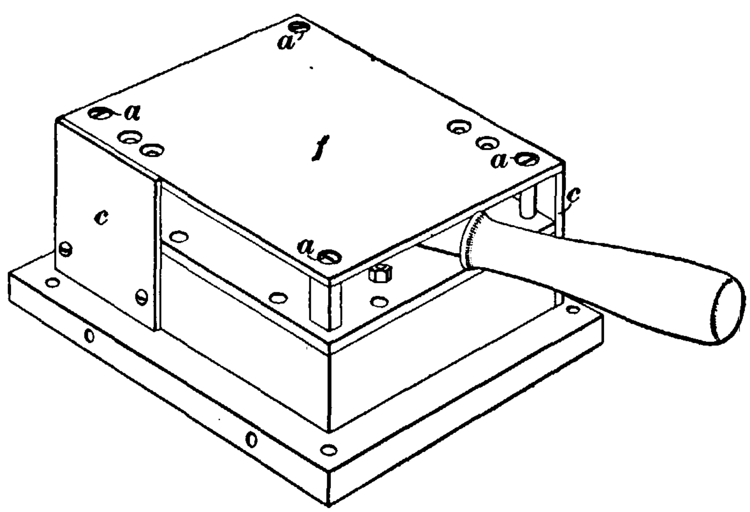

FIG. 16.

12. The General Electric Canopy Switch.—Fig. 16 shows one type of General Electric switch; the interior of this switch is readily exposed to view by removing the four corner screws *a*, *a*, *a*, *a* that secure the fiber top piece *f*. The fiber corner pieces *c*, *c* prevent the flash licking out and disfiguring the car roof, should the switch get a little out of order. This switch is provided with a magnetic blow-out to extinguish the arc; on this account, the switch blade is made of iron, because it carries the magnetism much better than brass or copper. Fig. 17 gives the general idea of how

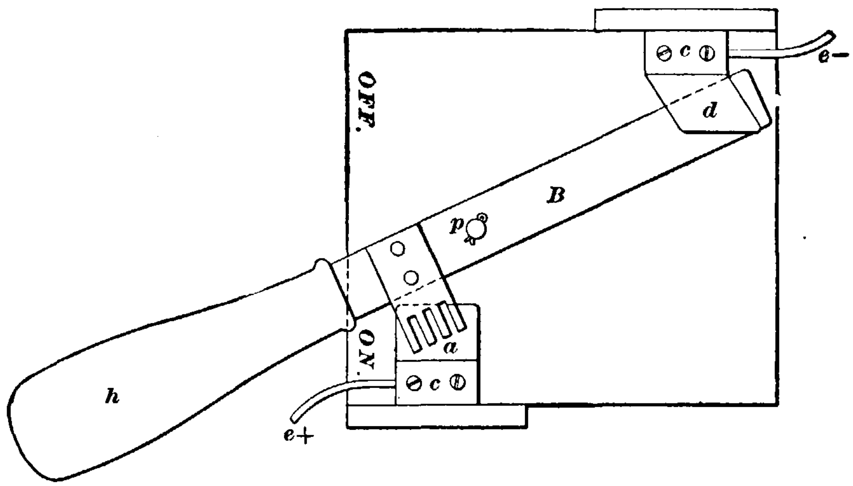

FIG. 17.

the switch mountings appear when the fiber top *f* is removed. *B* is the switch blade provided with handle *h*, working around a center *p*; *c*, *c* are brass castings provided with holes to receive wires *e*+ and *e*−, and also provided with spring blades *a*, *d*, into which the switch blade presses when the switch is on. When the switch is on, as shown in the figure, the path of the current is *e*+ –*c*–*a*–*B*–*d*–*c*–*e*–.

13. Fig. 18 illustrates the principle on which the blow-out coil works. *m* and *n* are two pieces of iron; *m* has a handle *h* and is movable around a center; *n* is stationary and has wound upon it a coil of wire that carries the main-motor current; one end of this coil is attached to *n* and the other end of the coil goes to one of

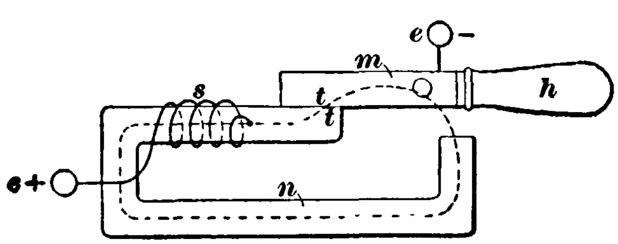

FIG. 18.

the connecting posts $e+$; m is connected to the other binding post $e-$. In the figure, the switch is shown closed; current is therefore passing through it, and the blow-out coil s causes magnetism to pass through the path indicated by the dotted line. As soon as the switch is open, the circuit is broken at t, t and the lines of force flowing across this point break the arc formed there. When the switch is opened, the magnetic and electric circuits are broken in the same place t, t and the magnetic field promptly extinguishes the arc. A switch adapted for use on a 500-volt circuit will not be reliable on a 1,000-volt circuit; nor will switches designed for motors of a certain horsepower work satisfactorily very long on a car equipped with motors of much greater horsepower, because the greater current causes so much more heating that the insulation on the magnetizing, or blow-out, coil gets roasted and becomes carbonized. When this happens, the current, instead of passing around the turns of wire and magnetizing the core, short-circuits through the burned insulation and produces little or no magnetism.

FUSE BOXES.

14. Use of Fuse Box.—It has been seen that the hood switch is a safety device and that it must be operated in case of an emergency by the motorman. The fuse box is also a safety device, but it is automatic in its action. If no fuse box is put on a car, the first time that a ground occurs on a motor or any of its controlling devices, the rush of current is very great and the weakest part of the circuit, that is, the part of least current-carrying capacity, will give way. This weak part may prove to be a loose connection in the car wiring or a bad contact in the controller; but it is more than likely that the weak spot will show up inside a motor, where the damage costs most to repair. The idea of the fuse box is to provide a weak part in the circuit; in case of an abnormal rush of current, the fuse in the fuse box should, therefore, blow before anything else gives way. To make sure that it will do so, the fuse wire is made smaller than any wire found in any of the devices or car wiring that are called on to carry the main current.

SIZE OF FUSE.

15. Factors Determining Dimensions of Fuses.—On a 30-horsepower equipment the armatures are generally wound with about a No. 9 B. & S. wire and the fields with about a No. 4 B. & S. or a No. 5 B. & S. wire, according to the nature of the work that the motor is called on to do. It would appear that in the selection of a fuse wire, it would only be necessary to choose a wire one size smaller than that in the field winding, but for several reasons, this is not so. The fuse wire must be a great deal smaller than the field wire. In the first place, the fuse wire is not embedded in insulation, and in the second place it is not running inside a closed motor, where it can be acted on by other heating influences than the actual current flowing through it. The result of its being outside, in an exposed place, is to give it plenty of air, hence facility to cool, so that for a given current its temperature will not rise as high as that of the wires inside of the motors.

16. Copper Fuses for 30-Horsepower Equipment.—As a result of experience, the copper wire used on a 30-horsepower equipment is about a No. 14 B. & S. A 30-horsepower motor running at full load takes a current of 45 amperes; two motors would, therefore, take a current of 90 amperes at 500 volts and the fuse wire would have to stand this current continuously if the motors always ran at full load. As a matter of fact, a 30-horsepower equipment running under the most usual conditions takes just about one-third of this current, or 30 amperes. Of course, there are times and conditions when the car will take more than 90 amperes, but these do not last long, and if they do, it goes to prove that larger motors are needed for the work, for no 30-horsepower railway motor will bear up under the strain of continual full load.

17. Copper Fuses for 50-Horsepower Equipment.—A 50-horsepower motor under full load at 500 volts calls for a current of about 75 amperes and a fuse wire proportionately larger than that used on a 30-horsepower equipment. The fuse wire should be about a No. 12 B. & S. gauge. The armature of a 50-horsepower street-car motor is wound with about a No. 7 B. & S. copper wire and the field with about a No. 2 B. & S.; so a No. 12 fuse wire gives plenty of margin. In the above it has been assumed that copper wire is to be used in all cases, because there is nothing special about it. It is cheaper than other special fuse wires and is just as reliable.

STYLES OF FUSE BOXES.

18. The Westinghouse Fuse Box.—Fig. 19 shows a perspective view of a Westinghouse car fuse box and Figs. 20 and 21 show how the removable block that takes the fuse wire is constructed.

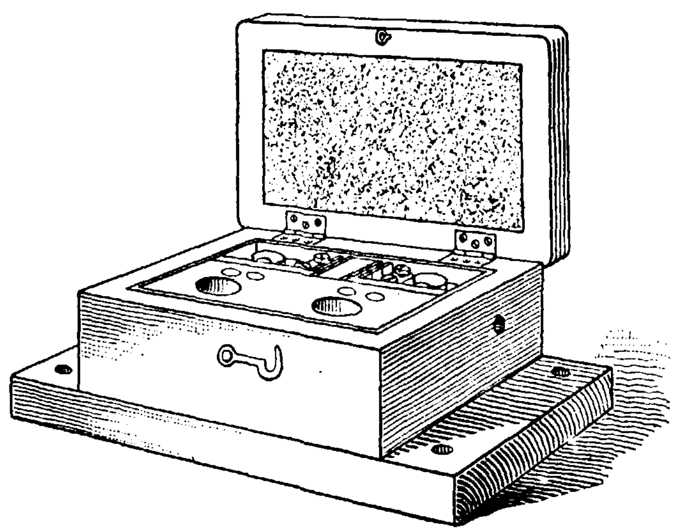

FIG. 19.

Fig. 20 shows the fuse box with the lid open; *a*, *a* are the two castings that receive the two ends of the trunk wiring through holes *d*, *d*; they are provided with switch blades to take the tongues *t*, *t* in Fig. 21. The box and also part *b* of the cover is lined with asbestos, so that the blowing of the fuse will not set the wooden case on fire. Holes *e*, *e* give the hot air and gases a chance to escape, so that when a fuse blows, the lid of the box may not be blown off. Holes *k* are for the screws that hold the fuse box up against the platform stem under the car.

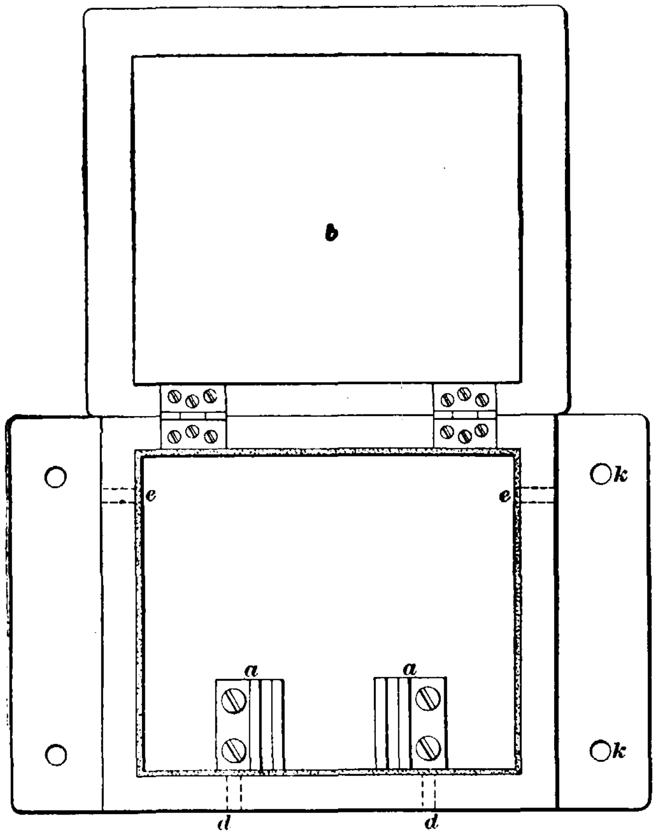

FIG. 20.

Fig. 21 shows the removable block to which the fuse wire is attached, as indicated by the dotted line; *b*, *b* are the two thumbscrews by means of which the ends of the fuse wire are secured; *c*, *c* are two finger holes used to withdraw the block when it is necessary to put in a fuse. This fuse box has the great advantage that a fuse can be put in without any danger of getting a shock, even though the trolley pole may be left on and both canopy switches closed. This figure shows the fuse wire loose, in order that it may be more easily seen; however, the three sides *o*, *s*, *p* have a groove cut in them, and the wire is drawn into this groove.

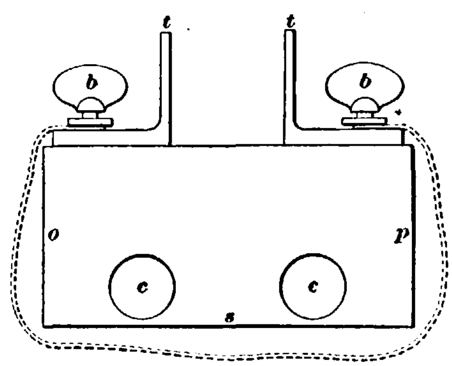

FIG. 21.

19. The General Electric Fuse Box.—Figs. 22 and 23 show one form of General Electric fuse box that is very much used. In Fig. 22, *a*, *a* are two holes through which the trunk wire passes into and out of the fuse box; on each end of the box is a hole *b*, through which a screwdriver may be put to loosen or tighten screws *b*, *b*, shown in Fig. 23 (*a*); *c* is a rawhide flap that serves as a weather protector. A substantial lid is unnecessary on this fuse box, because the presence of a magnetic blow-out coil *d*, Fig. 23 (*a*), allows very little arcing when a fuse blows. Fig. 23 (*a*) shows the member that fits into the wooden

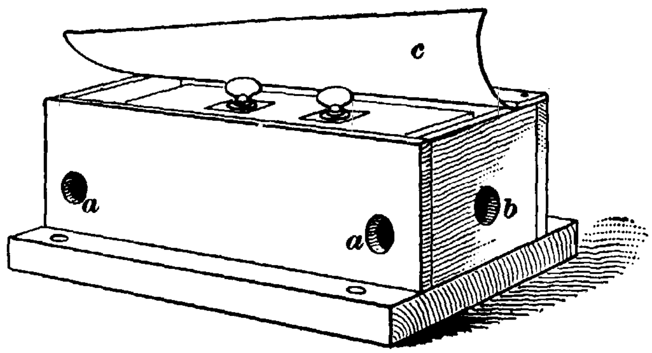

FIG. 22.

case shown in Fig. 22; *a*, *a* are two lugs provided with holes *e*, *e* to take the ends of the trunk wire and screws *b*, *b* to secure the wire in place; *c*, *c* are also two lugs provided with thumbscrews to take such a special fuse wire as is shown in Fig. 23 (*b*). This special fuse with terminals and made of regular fuse wire is not necessary, as almost any fuse wire can be secured under the thumbscrews, but it is a good thing because it makes sure that in a majority of

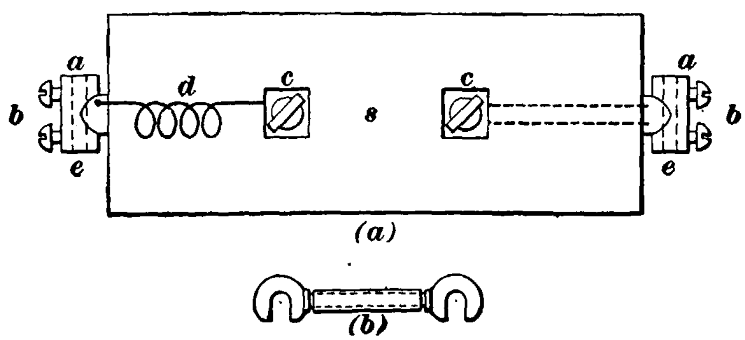

FIG. 23.

cases the car is provided with a fuse of the proper size. On one side, *a* and *c*, Fig. 23 (*a*), are connected directly together, but on the other side they are connected through coil *d*, which has an iron core so disposed as to throw a strong magnetic field across the space *s*, where the fuse blows. This fuse box does good work when in good order and will only give trouble when continuous abuse causes the blow-out coil to become short-circuited.

CIRCUIT-BREAKERS.

20. Circuit-breakers have been used for a number of years in street-railway power houses, but their use on street cars is of comparatively recent date. The circuit-breaker, as its name implies, is a device for opening the circuit between the trolley and ground whenever the current, for any reason, becomes excessive. On a street car they occupy the position usually taken by the hood switches; in fact, they are practically an automatic hood switch, and therefore serve the combined purpose of hood switch and fuse box. Fuses are always more or less unreliable. Sometimes they blow when they should and sometimes they do not. The circuit-breaker is essentially a switch that is held closed against the action of a spring by a catch or trip attached to the armature of an electromagnet. The current from the trolley passes through the coil that forms the electromagnet, and if for any reason the current becomes excessive, the armature is attracted, thus releasing the catch and allowing the switch to fly open. The circuit-breaker does not, therefore, depend on any heating action for its operation, and hence works almost instantaneously and with much more reliability than a fuse.

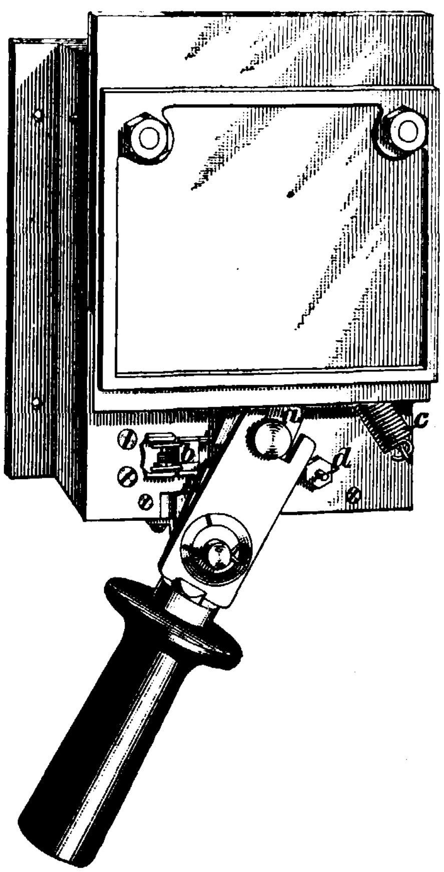

FIG. 24.

Circuit-breakers used on cars are generally arranged so that the arc formed at the break takes place in a magnetic field and is thus blown out in the same way as in a controller. Fig. 24 shows a car circuit-breaker. In general appearance it is much like a hood switch; *a* is the switch blade and *b* is the catch that holds it in position against the action of the spring *c* when the breaker is set. A blow-out coil is contained in the box, and this forms a magnetic field by which the arc is extinguished. The nut *d* is used to adjust the current at which the breaker trips, by varying the tension on a spring against which the armature has to pull.

21. Fig. 25 shows another circuit-breaker of larger capacity. This type is also used on cars equipped with heavy motors. When so used, it is in many cases mounted in a box with the handle *h* projecting at one end. *A* and *K* are the terminals of the breaker and *B* is the tripping coil, which also serves to set up the magnetic field necessary for blowing out the arc. *X* is the armature of coil *B* and is pulled down against the action of the spring *S* whenever the current exceeds that for which the breaker is set. The tripping current is adjusted by means of nut *T*. The iron plate *P* and a similar one back of it are magnetized by the current in coil *B*, and as the break takes place between these two poles, the arc is promptly extinguished by the field that exists there. Fig. 26 will give an idea as to the principle of operation. *A* and *K* are the terminals, *d d* is a contact that is forced up against *F*, *F* when the breaker is set. The current then takes the path *A–B–F–d d–F–K*. When the breaker trips, the contact piece *d d* flies down and the tendency is for an arc to form between *F*, *F*; the magnetic field blows the arc upwards, and whatever burning takes place is on the contacts *E*, *E*, which are so constructed that they may be readily renewed. When it is desired to trip the breaker by hand, the knob *N*, Fig. 25, is pressed.

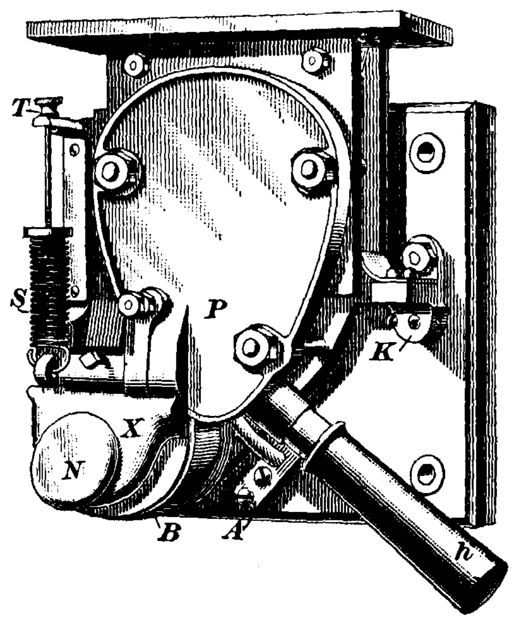

FIG. 25.

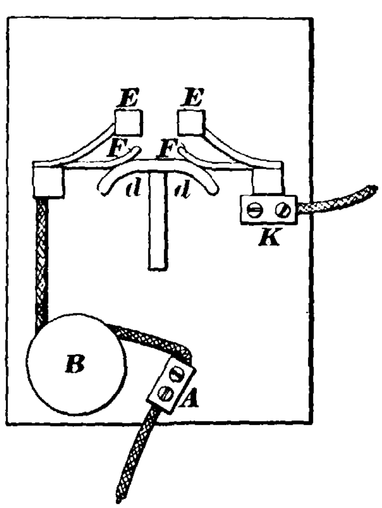

FIG. 26.

STREET-CAR LIGHTNING ARRESTERS.

22. Each car should be equipped with a lightning arrester and in some cases, on the larger cars, two arresters are provided. The arresters used on cars do not differ materially from those used for other work and which have been described previously. The arresters made by the General Electric Company are of the magnetic blow-out type and are mounted in a porcelain case. The Westinghouse car arrester extinguishes the arc that would otherwise follow the discharge by confining it between two lignum-vitæ blocks, where it is smothered out. A lightning arrester used on street-railway service is used under especially severe conditions, because every discharge to ground gives rise to a short circuit, since one side of the system is grounded. The arresters should be inspected from time to time to see that their air gaps are in good order.

23. Westinghouse Arresters.—Fig. 27 shows the Westinghouse car lightning arrester; (*a*) shows the arrester with the iron cover on and (*b*) with the cover off. The

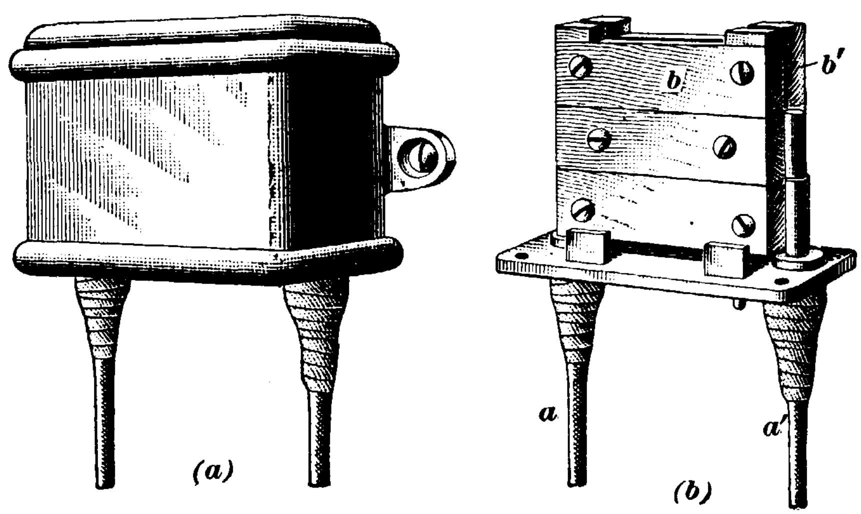

FIG. 27.

wires *a*, *a'* pass through the bottom and connect to the terminals, which are clamped between the blocks *b*, *b'*. These terminals are separated a short distance, and the space between them is bridged over by a number of charred grooves, across which the discharge leaps. Fig. 28 shows the arrester as mounted on a car in connection with a choke coil. The ordinary choke coil used on street cars consists of 10 or 12 turns of wire wound on a wooden core about 2 inches in diameter. The coil shown in Fig. 28 is wound on a grooved wooden core and bare wire is used. A

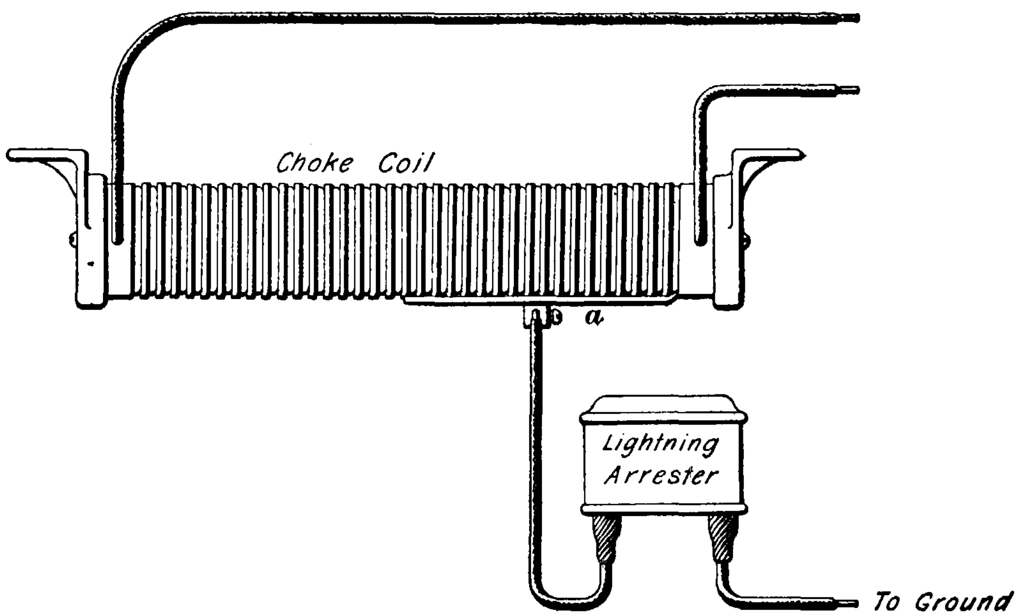

FIG. 28.

copper strap is connected to the line terminal of the arrester and is placed in close proximity to the turns of wire. When a discharge comes in over the line, it can jump from any of the convolutions to the strap and thus pass off through the arrester to the ground. In the great majority of cases, however, the plain choke coil is used.

24. Inspection of Lightning Arresters.—All lightning arresters of whatever make should be inspected after each thunder shower, for even if the arresters themselves are in good shape, there may be some loose or broken connection in a wire leading to or from the arrester. If the ground wire is broken or disconnected, the arrester might just as well not be on the car at all.

The principal point to be observed about an arrester is that the air gap should be thinner or more easily punctured than any of the insulation to be found on the motors or the controllers. If inspection is neglected and, through the burning and jolting of the car, the air gap is allowed to get thicker than the insulation it is to protect, the lightning will jump through the insulation, rather than jump across the air gap.

25. Connections for General Electric Arrester.—Fig. 29 is a diagram of the General Electric Company's latest type of magnetic blow-out arrester, and shows the manner of connecting the arrester. A carbon resistance *z l* is divided into two parts, *r′* and *r*; part *r′* is in multiple with the blow-out coil *d* and part *r* is in series with both and serves to limit the value of the trolley current that always follows the discharge across the air gap *a*. One end of the blow-out coil *d* is attached to one side of the air gap and to one end of the carbon resistance at *z*; the other end of the coil is attached to the carbon resistance at point *p*. The trolley connection enters at the upper left-hand side of the case and connects to one side of the air gap. In the figure, *t* is the trolley wire leading *to* the fuse box; *t′*, the wire leading *from* the fuse box; *k* is the choke coil; *f* and *a*, the motor field and armature, respectively; *g*, the motor ground and *g′*, the lightning-arrester ground, running from the main ground wire to a post in the lower right-hand end of the box. Ordinarily, the path of the current is *t–t′–k–f–a* and to the ground at *g*; as soon as lightning strikes, it takes the path *t–t′–t″–a–n–z–p–l* and to the ground at *g′*; on reaching point *n*, it has two ways of getting to point *p*—through the carbon resistance by way of path *n–z–p* and through the blow-out coil by way of path *n–x–d–y–p*; since the blow-out coil acts as a reactance coil, the

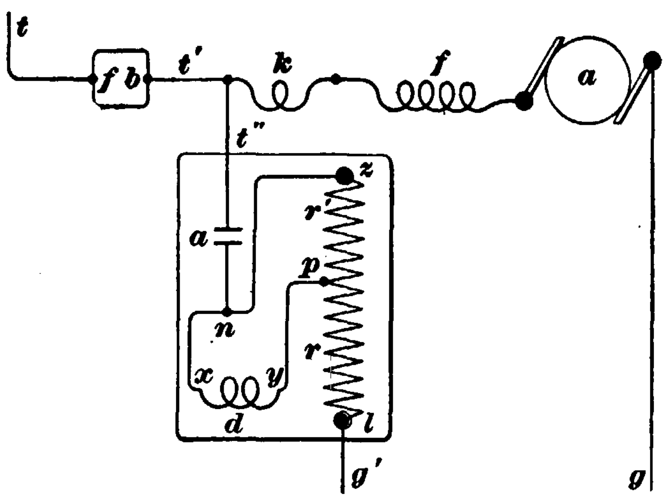

FIG. 29.

first sudden discharge prefers to take the carbon non-inductive path in multiple with it. In passing through the coil, the current sets up a strong magnetic field across the gap *a*; the arc is put out and the arrester is ready for the next discharge.

RESISTANCE COILS.

26. Reasons for Use of Resistance Coils.—The resistance coil, sometimes called the starting coil, is a device that is used to limit the value of the current at starting; this permits the car to be started smoothly without jerking and protects the motors from the undue strain that would result from an excessive current. It must be borne in mind that wherever there is resistance in a circuit through which a current flows, there is heat, and wherever there is heat, there is a loss of energy that cannot be converted into useful work. If it were not for this fact, the motors themselves could be so wound that they would have resistance enough to hold the current down to a safe value at starting; but then this resistance would, to a greater or less degree, be in circuit all the time and there would be a constant and excessive loss of energy due to heating. It is very often the case that cars run slower after they become well heated than they do when they make their early trips. This effect is very noticeable on heavy cars equipped with old-style motors. In order, then, that the equipment shall waste as little power as possible, the resistance of the motors is made very low; on account of this very low resistance, the line pressure of 500 volts would send through the motors an enormous starting current that would not only start the car with a jerk, but would strain the motors and gearing; to do away with these two bad effects, the starting coil is used. This coil is intended to be used only on the starting notches of the controller; when the running notches are used, the coil is entirely cut out and cannot, therefore, have any effect upon the maximum speed of the car.

27. Running Cars on Resistance Notches.—It is a very bad practice to run a car for any length of time on a resistance notch. There are three reasons for this: in the first place, it is not an economical notch on which to run, because the heating of the coil means just so much energy wasted; in the second place, the coil is designed only for the temporary use of starting, and when continuously used for slow running, it gets so hot that the insulation is destroyed, the coil is short-circuited, and the car is made to start with a jerk; in the third place, accordingly as one running notch or the other is used for running purposes, one part or the other of the coil will be abnormally heated.

28. General Electric Resistance Coil.—Fig. 30 shows a type of starting coil made by the General Electric Company. It consists of ordinary band iron folded back and forth with a ribbon of asbestos in between each fold. This iron and asbestos is built up into divisions *d* called panels, and these divisions are held in insulating bricks *a* and clamped firmly by means of the end plates *b*, *b* and bolts *c*. The whole is hung from the car floor by means of the feet *e*, *e*. The terminals of the different sections into which the resistance is divided are connected to the binding posts *f* that receive the wires that come from the car hose and connect to the two controllers. For resistances used in connection with heavy traction work, a similar construction is followed, except that instead of a folded iron strip insulated with asbestos, a cast-iron zigzag grid is used. This makes a very substantial and well-ventilated resistance.

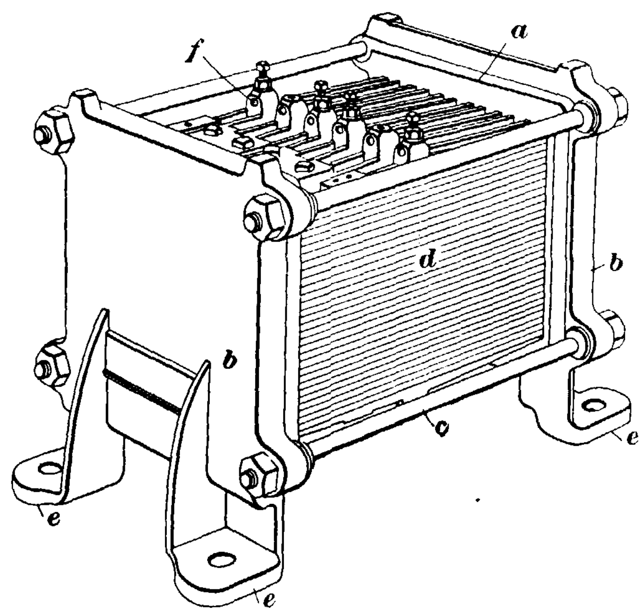

FIG. 30.

29. Westinghouse Resistance Coil.—In Fig. 31 is shown the type of resistance coil made by the Westinghouse Company. This coil is made of band iron insulated entirely with mica, and up to certain limits of abuse it is not affected by either heat or water. A single coil, such as that shown in the figure, is called a barrel, and the proper starting coil for any size motor can be made up of two or more of these barrels. Fig. 32 shows the method usually adopted for hanging a two-barrel starting coil. Where more barrels are required, more sets can be hung in the same manner alongside one another. In Fig. 32, *a*, *a* are two of the car sills; *b*, *b* are two strap-iron hangers through which passes a rod *d d* supporting coils *c*, *c*. Fig. 33 shows Westinghouse resistance coils mounted in an iron frame.

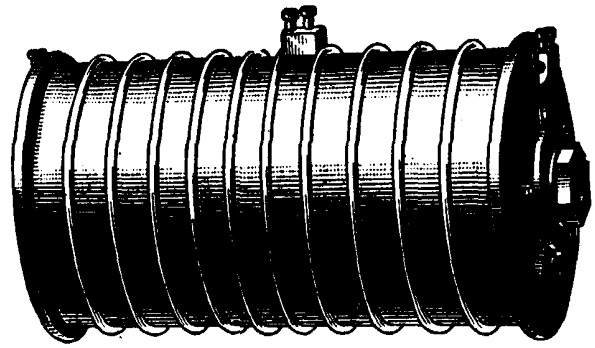

FIG. 31.

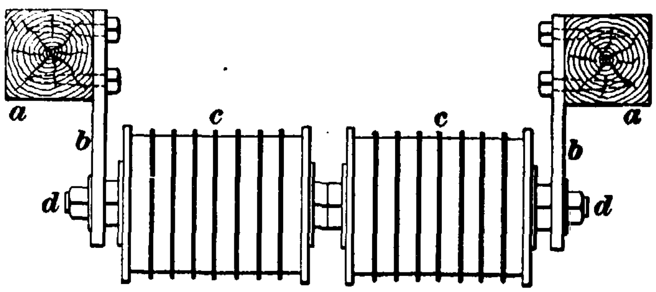

FIG. 32.

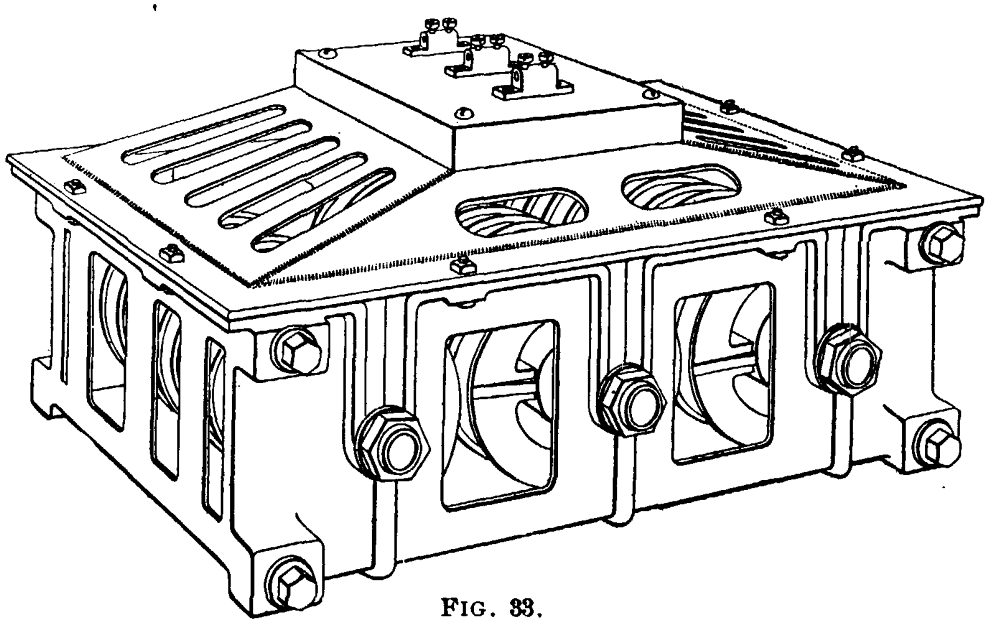

FIG. 33.

ELECTRIC CAR HEATING.

30. Introductory.—So far we have confined our attention to the uses to which electric current is put for driving the cars. Current is, however, also used for heating and lighting them, and it is necessary to consider the appliances and methods used for this purpose. It has already been explained that if a current is sent through a wire, it always encounters a certain amount of resistance and the wire becomes heated. If the power used in forcing the current through the wire is large, the temperature of the wire will be high and the wire may be brought to a red or even a white heat. When the heating effect is sufficient to bring the conductor to a white heat, light is produced, as in the case of the incandescent lamp. In ordinary line wires, there is a heating effect, but the resistance of the wire is so low that the rise in the temperature of the wire is not noticeable. When the temperature is very high, as in an incandescent lamp, it is necessary to mount the conductor or filament in a vacuum, so that there will be no oxygen present to oxidize it. In electric heaters this is not usually necessary, as the temperature at which the wire is worked under normal conditions is not high enough to cause damage.

31. General Remarks on Heater Construction.—All electric heaters are made on the same principle—that of enclosing a high-resistance wire in a case that is designed to keep the feet and clothing of passengers out of range of the hot wire. According to the size of the car and the make of the heater, 4, 6, 8, 10, 12, or even 20, heaters are required per car. For a given amount of heat required, the smaller the heater and the more of them that are used, the more evenly will the heat be distributed through the car, but the more places will thus be created where trouble is liable to arise.

As regards efficiency, heaters of all makes are about the same. To keep a 20-foot closed car comfortable during average weather in the vicinity of New York requires a current of about 10 amperes at 500 volts. This means that between 6 and 7 horsepower is used to heat a car. It is easily seen, then, that it costs considerable to heat a car by electricity and that when the heaters are in use, there is a considerable additional load thrown on the station. On the other hand, electric heaters occupy no passenger space, they distribute the heat more uniformly than stoves, they are cleaner, and they allow the heat to be more easily regulated. For these reasons, the electric heater is extensively used, even though it is more expensive to operate than a coal stove. Electric heaters are nearly always installed in such a manner that at least three different degrees of heat may be obtained by operating a **heater switch** that changes the connections of the heaters.

The number of different makes of heaters is so large that it would be out of the question to treat all of them here. We will, however, describe one or two typical examples in order to illustrate the method of connecting. The connections for the different makes are much the same.

EXAMPLES OF ELECTRIC HEATERS.

THE JOHNS HEATER.

32. In the **Johns** system of car heating and in most other systems, the heaters are distributed through the car. In cars in which the seats run lengthwise, the heaters are hung along the seat panels on both sides; in cars with cross seats, they are placed under the seats. The resistance wires of the Johns class E heaters are completely covered with asbestos thread and are then woven into a mat, the warp of which consists of asbestos cords. The heater thus formed is thoroughly impregnated with a special insulating compound baked in at a high temperature and is thus made waterproof. The heater is then attached to a backing of asbestos millboard that has been prepared in the same way. The completed heater is put in a perforated steel casing and the electrical connections are made by means of binding posts on porcelain bases at each end of the heater.

33. Connections for Johns Heaters.—Fig. 34 gives the general outline of the Johns class E heater and also shows how the wires on the inside are brought out to the binding posts *O*, *O*, *O*, *O*; the resistance wire in the heater is in two parts that do not touch each other anywhere. In Fig. 34, *A* is the top part and *B* the bottom part; the binding posts to which they connect are set on porcelain bases *M*, which, of course, keep them apart. Wires *A*; *A* and *B*, *B* on the ends connect the heaters together on the inside of the panel, as shown in Fig. 35, which is a section of a closed-car seat with a

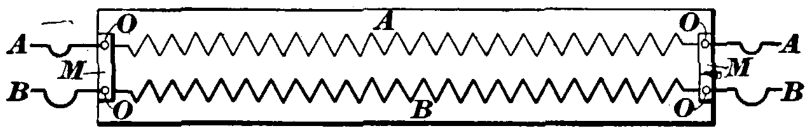

FIG. 34.

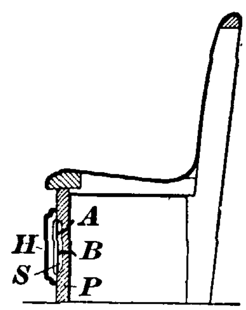

FIG. 35.

class E heater mounted upon it. In Fig. 35, *A* and *B* are the wires by means of which the heaters are connected together; *H* is the heater; *P*, a cross-section of the seat panel; and *S*, a space between the back of the heater and the face of the seat panel.

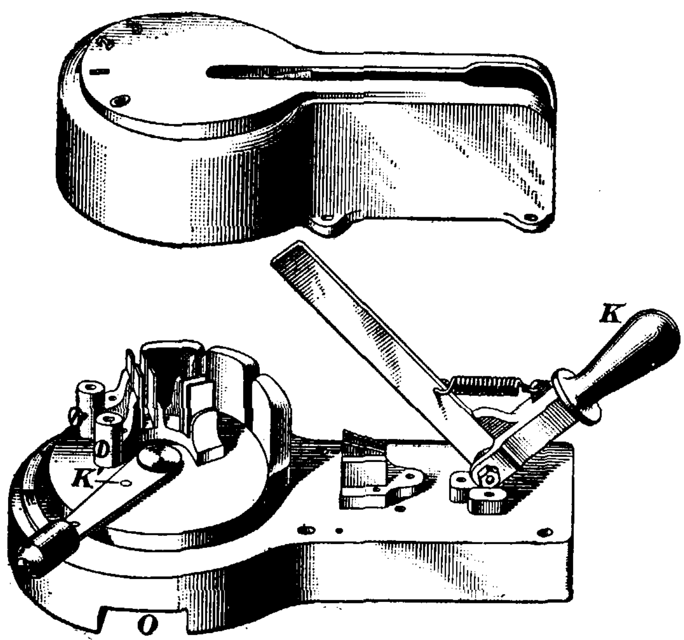

FIG. 36.

34. The Johns Regulating Switch. Fig. 36 shows the Johns heater switch. The main point about this switch is that before any change can be made in the combination in which the heaters are running, the main heater circuit must be opened. In Fig. 36, switch K opens and closes the heater circuit and blade K' makes the combinations corresponding to the several marked notches indicated by the dotted lines on the heater case in Fig. 37. By such an arrangement, all tendency to blister and burn is confined to a quick-break

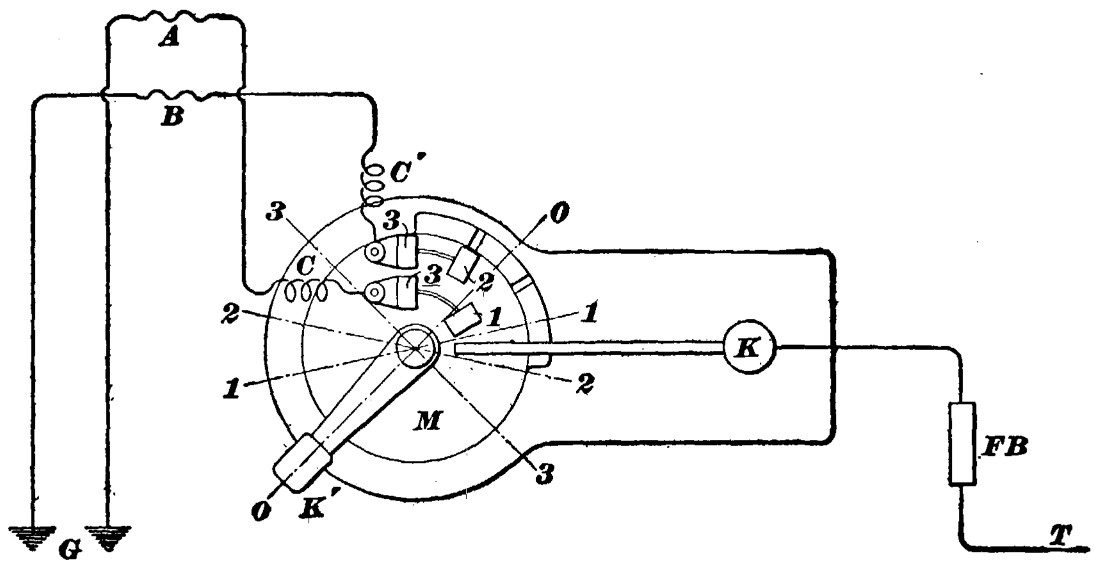

FIG. 37.

knife switch that will not be damaged to any extent by it. As long as the knife switch is open, the current is off and the regulating switch K' can be moved to any of the four notches without danger of burning; but when K is closed, K' cannot be moved at all; also, unless the regulating switch is exactly on the notch, switch K cannot be closed.

35. Fig. 37 is a diagrammatic sketch of the connections of the Johns heater switch. In the figure, the switch is at

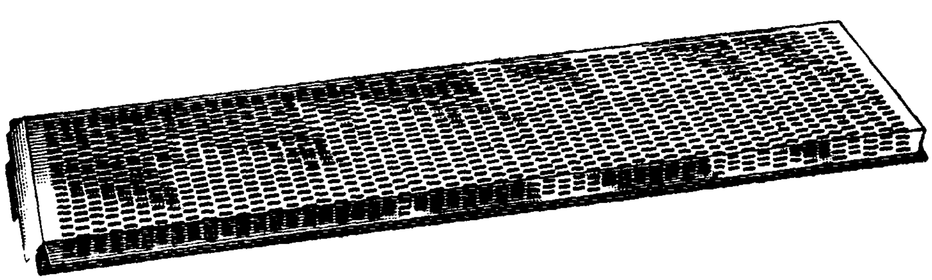

FIG. 38.

the off-, or *0–0*, position, so that no current can flow through the circuit; when K is open and K' is turned to the first notch, indicated by the dotted line *1–1*, contact jaws *1*, *2*, and *3* swing with K' and jaw *1* falls into line with K, so that when K is closed, the path of the current is T–$F\,B$–K–*1*–*3*–C, through the top or A part of every heater, to the ground at G. When K' is moved to the second notch, jaw *2* falls into line with K and the path of the current becomes T–$F\,B$–K–*2*–*3*–C', through the B or bottom sections of all the heaters, to the ground at G. On the third notch, both jaws *3* fall into line with K and the current divides between the A and B sections of all the heaters. Jaws *3* do not touch each other, but each connects to a binding post to which the heater circuits connect. Fig. 38 is a view of the class E Johns heater, complete, ready to be put in a closed car.

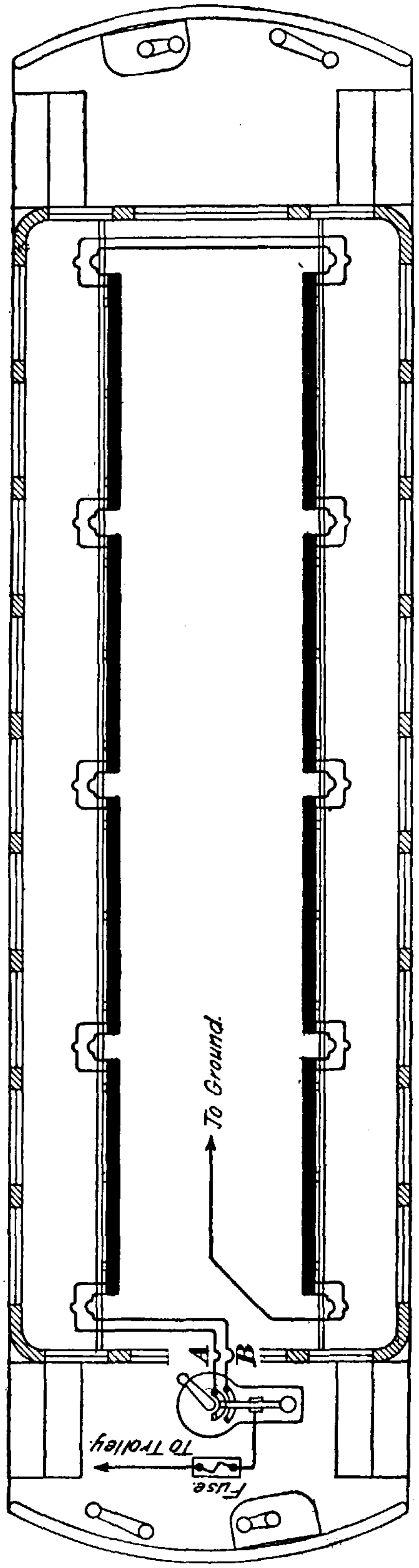

FIG. 39.

36. Car Wiring for Johns Heaters.—Fig. 39 is the car-wiring diagram for a set of class E heaters, eight to a set; the top section of each heater connects to the top section of the heater next to it, and so on all around the circuit. Care must be taken that the top and bottom wires are not confused.

THE CONSOLIDATED HEATER.

37. Construction.—Fig. 40 shows the coil used in the consolidated heater, and which is constructed as follows: On a stout iron rod are strung porcelain tubes that run the full length of the heater. These pieces have a spiral groove in them and are put on the rod so that a continuous spiral groove runs the full length of the core. The heater coil is placed in this groove. This way of arranging the coil places

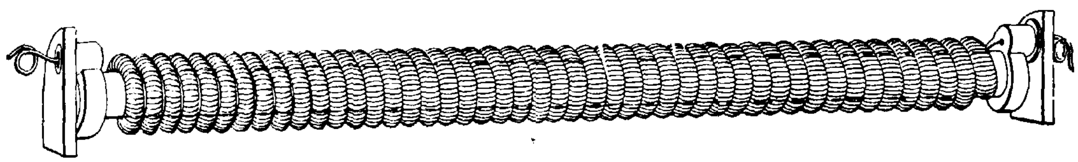

FIG. 40.

a great amount of wire in a given space and gives the air a good chance to get at all parts of it. The terminal wires that run out of the case at each end, through porcelain bushings, are attached to the ends of the coil by twisted and soldered joints and are well secured without the aid of binding posts. In each heater are two coils, like that shown in Fig. 40, placed one above the other. The top coil has the greater resistance.

38. Fig. 41 shows the type 143L heater with the front plate removed to show the two coils in place. The

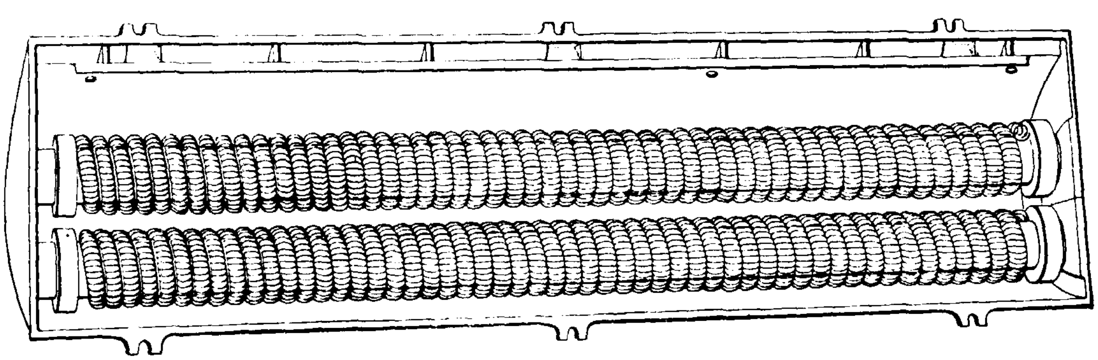

FIG. 41.

143L heater is for a side-seat closed car and is intended to be set flush with the panel of the riser.

The wiring for these heaters is carried out as shown in Fig. 42.

39. Consolidated Heater Switch.—Fig. 43 shows the heater switch with the cover on and off. This switch will handle 30 amperes at 500 volts. The spring-brass contact plates are mounted on a glazed porcelain base and the arm of the switch is of composition insulating material. The

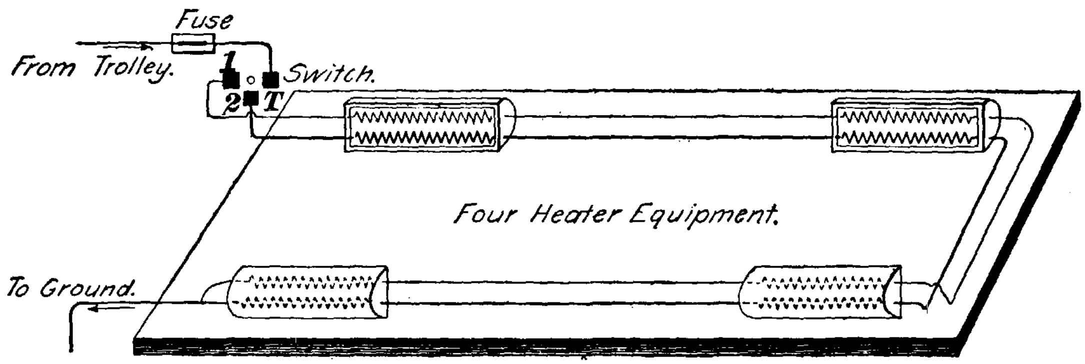

FIG. 42.

position on which the switch rests is clearly shown by a dial number that appears through a hole in the cover. In both views of Fig. 43, the switch is on the third point; on this point, the current goes in on the right-hand side of the switch at the post marked *T*. The three arms *a*, *b*, *c* are

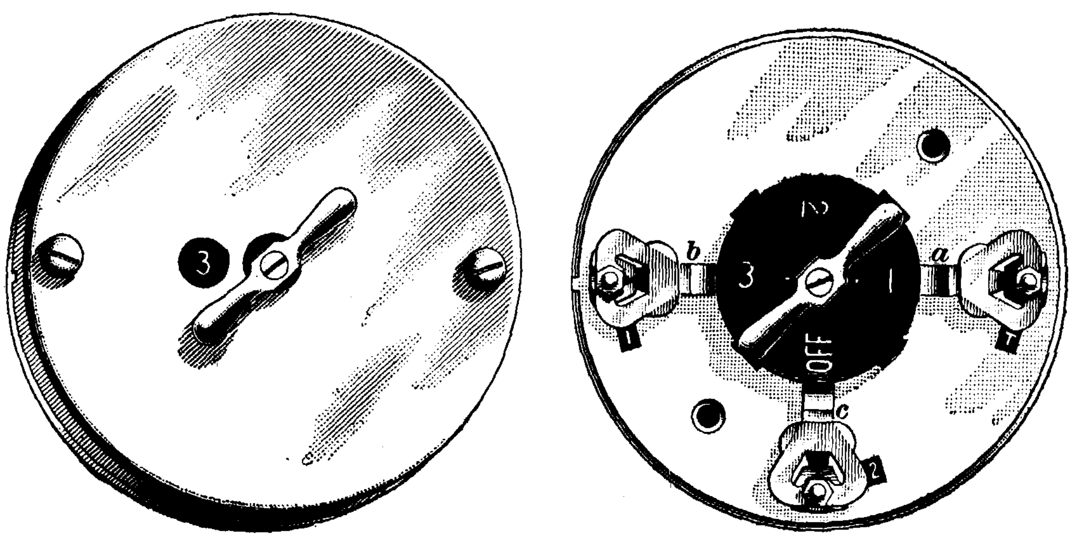

FIG. 43.

all connected together so that the current splits; part of it goes across the *b* arm to post *1* and thence to the circuit through the top part of all the heaters; the other part goes across arm *c* to post *2* and thence to the circuit through the bottom part of all the heaters. If the handle be given a quarter-turn to the right, arm *a* leaves post *T* and goes to post *2*; arm *c* leaves post *2* and goes to post *1*; arm *b* leaves post *1* and does not go to any post at all; so post *T* is left without any connection and the switch is dead except on post *T*. If the switch is given another quarter-turn, arm *a* goes to post *1*, arm *b* goes to post *T*, and arm *c* leaves post *1*, but does not go to any post at all, so that current can only flow through the top of the heaters, which is the combination on the first point. One more quarter-turn takes arm *b* from post *T* to post *2*, arm *c* to post *T*, and arm *a* from post *1* to no post at all. On this point, then, post *1* has no connection and current flows through only the bottom part of the heaters.

40. Troubles With Heaters.—Figs. 44 and 45 show how simple mistakes may cause trouble. In Fig. 44, H, H_1, H_2, H_3 are four heaters in series across the line and the path of the current through them is T–H–H_1–H_2–H_3 to the ground at G. When connected thus, these heaters take all the current that they should have. Now, suppose that on account of some poor wiring, the wire joining heaters H_1

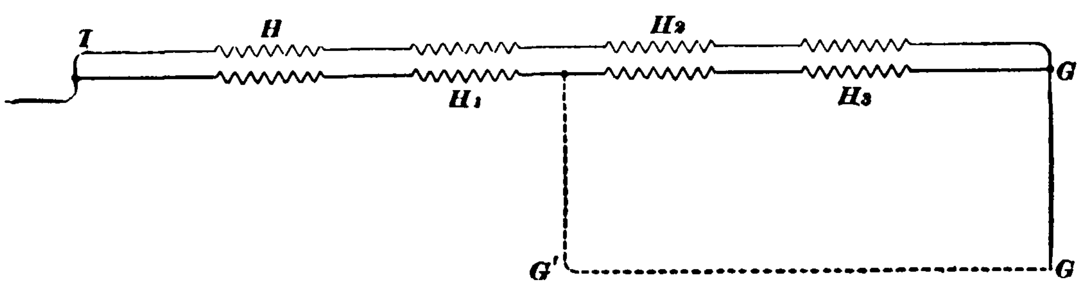

FIG. 44.

and H_2 comes into contact with a truss rod, brake rod, sand box, etc., making a ground at G'. The current goes through the top part of all the heaters the same as it did before, because that is not grounded, but the path of the current through the bottom sections becomes T–H–H_1–G'; two heaters H_2 and H_3 have their lower sections cut out entirely, and the lower sections of heaters H and H_1 are across the line alone. The result is that these sections burn out.

Fig. 45 illustrates a case of getting the top and bottom heater leads confused. The upper sketch (*a*) shows six heaters connected as they should be. In Fig. 45 (*b*), all the heaters have been connected properly except the last one, where the top and bottom leads have been crossed, with the result that the fine-wire coil in the H_5 heater is in series with the coarse-wire coils in all the other heaters, and the H_5 coarse-wire coil is in series with the fine-wire coils in

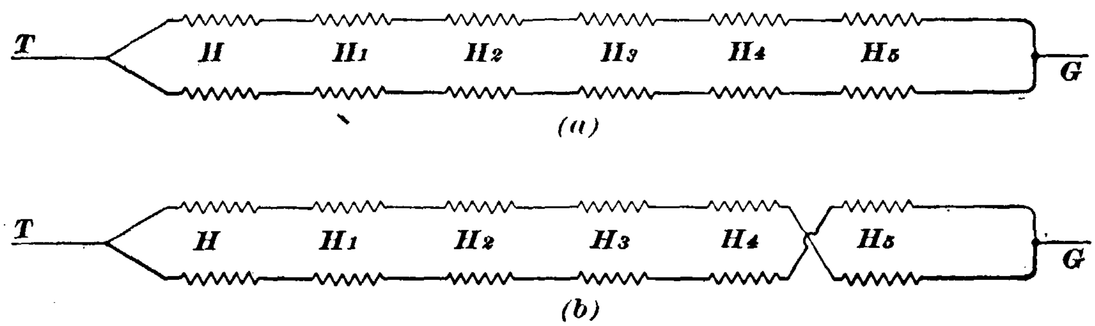

FIG. 45.

the other heaters. This is not so hard on the fine-wire coils in series with the H_5 coarse-wire, because the effect is shared by each of the five heaters ahead of the fault; but it is hard on the H_5 fine-wire coil, because the five coarse-wire coils with which it is in series pass more current than it can stand. The result is that unless the trouble is found in time, the top part of the H_5 heater will become red hot and burn out or it will melt its soldered connection.

CAR LIGHTING.

THE LAMP CIRCUIT.

41. General Remarks.—The lamp circuit is one of the most important parts of a car's equipment, and it may be of great assistance to the crew if they know how to use it. In the first place, if the lamp circuit is kept in such condition that it may always be relied on to burn when there is any power on the line, it becomes a ready means of telling if the power is on or not. If a car refuses to move and if there is no flash in the controller when the power drum is thrown on and off, the next thing to do is to turn on the lamp switch to see if the lamps will burn; if they burn, the power is, of course, on the line, and the car's failure to move must be due to a fault in the motor circuit. Though if the lamps do not burn, it is by no means safe to draw the conclusion that no power is on the line, because their failure to burn may be due to a fault in the lamp circuit itself. The two places where such a trouble most often occurs are where the ground wire is fastened to the truck or motor and in the main light switch, if there is one, that controls all the lamp circuits. The main seat of trouble, though, is in the ground wire; never fasten the lighting ground wire to the motor or to the truck.

42. Switches for Car-Lighting Circuits.—Fig. 46 shows a type of single-pole lamp switch that is largely used. It can be used to control a single independent circuit or any number of circuits within its capacity, if all the circuits can

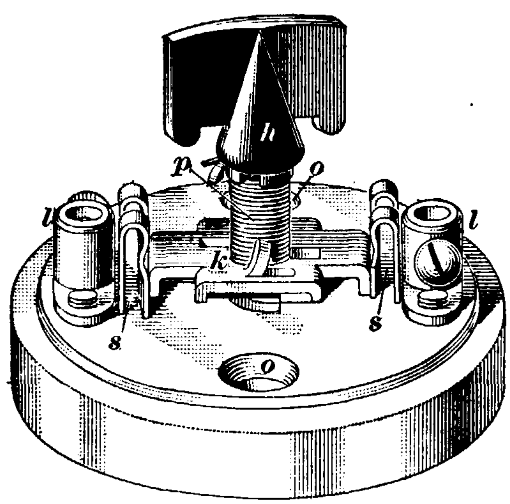

FIG. 46.

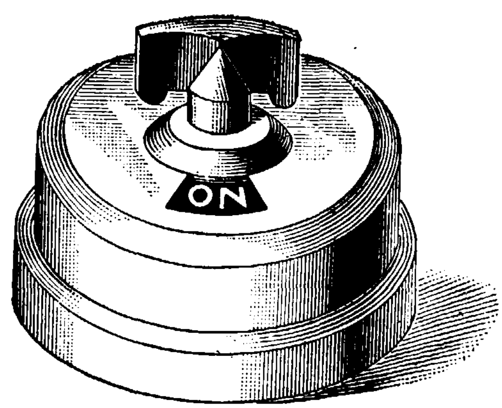

FIG. 47.

be put in multiple. The lamp wires pass under the porcelain base through two grooves made for that purpose and come up into posts *l*, *l*, where they are held by screws. When the key *h* is turned to the right, spring *p* winds up as far as possible and switch blade *k* then jumps loose from contact tips s, s and breaks the circuit in two places. Fig. 47 shows the appearance of a switch with the cover on.

43. Fig. 48 shows an ordinary three-way switch that is commonly used on cars for cutting the headlight out and the tail-light in, or *vice versa.* On the switch shown in Fig. 48 there are, besides the switch blade k, four spring contact clips L_1, L_2, L_3, L_4, three of which have a post to take a car wire and one of which, L_1, has no post. Inside the switch base, L_1 is connected to L_2; the trolley wire goes to the post on L_2, so that there are on the switch two trolley posts L_1 and L_2, and no matter in what position k may be, one end of it is bound to make contact with a trolley post. When k is in the position shown in the figure, the current comes in at L_2, goes over to L_1 by way of the inside connection, crosses k, and goes out on the L_3 wire. If k is given a quarter-turn, the current comes in on L_2, crosses on k, and goes out on the L_4 wire. When controlling two independent circuits or when used to cut in and out alternately two parts of the same circuit, the three-way switch has no off-position.

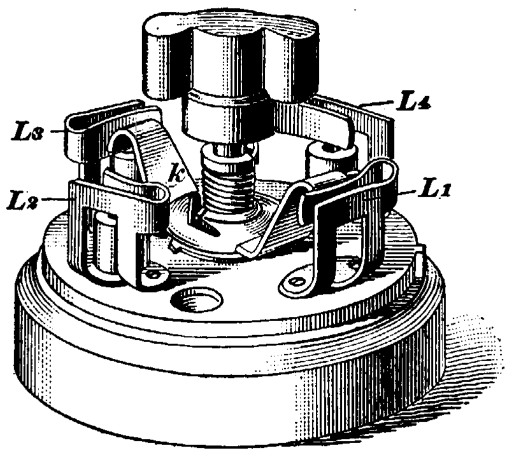

FIG. 48.

44. Westinghouse Plug Switch.—Fig. 49 shows the Westinghouse Company's three-way plug switch. A is a disk of hard rubber about $3\frac{1}{2}$ inches in diameter and about $1\frac{1}{4}$ inches thick. In it are three metal-lined holes T, *1*, *2*, each with a metal bottom. By means of posts not shown in the figure, one circuit is attached to the metal sheathing of hole *1* and the other to that of hole *2*; the trolley wire connects to the sheathing of hole T. B is a **U** plug with a rubber handle; holes *1*, *2*, and T have no connection with one another until plug B is shoved into place; if B is put into the two left-hand holes, the current comes in on wire *T* and goes out on wire *1*; if *B* is put into the two right-hand holes, the current comes in on wire *T*, as before, and

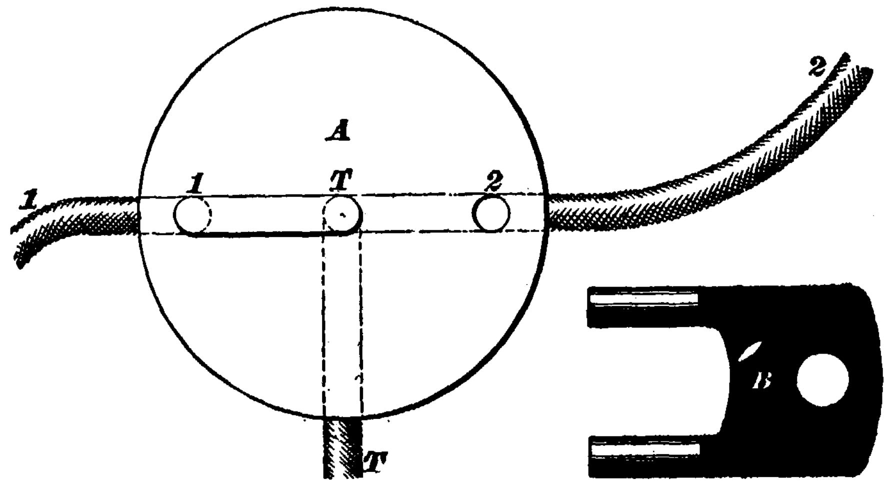

FIG. 49.

goes out on wire *2*. If plug *B* should get lost, a piece of No. 4 B. & S. rubber-covered wire bent into a U will answer.

CONNECTIONS FOR LAMPS.

45. Single Lamp Circuit.—The lamps used for lighting cars require from 100 to 110 volts across their terminals; hence, in order to operate these lamps on a 500-volt circuit,

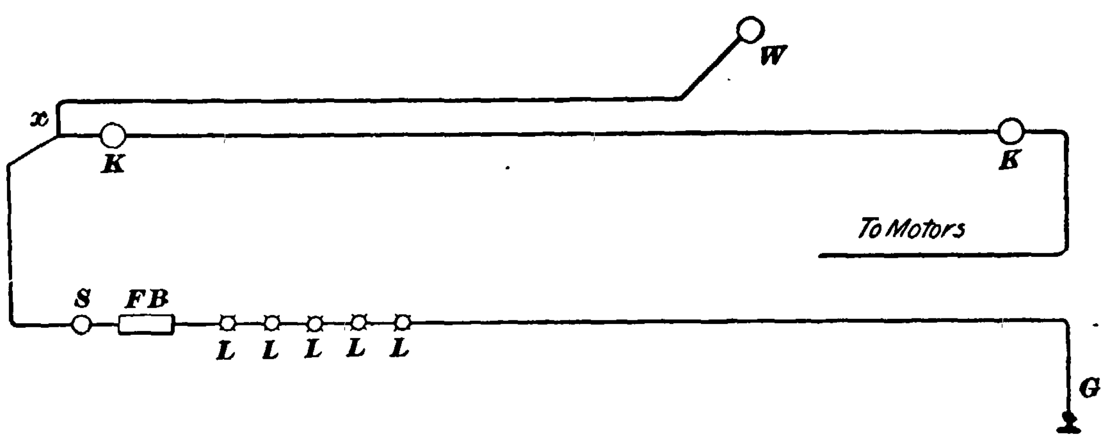

FIG. 50.

they must be arranged so that there will always be five in series between the trolley and ground. It is not practicable to make lamps that will burn directly across 500 volts. Fig. 50 shows a single five-light lamp circuit with all the lamps inside of the car; in such a case, an oil headlight or sign light must be used. The lamp circuit is tapped to the trolley roof wire ahead of both hood switches, so that the opening of either of these switches will not put out the lamps. *S* is a single-pole snap switch and *F B* the lamp fuse box.

46. Fig. 51 is the wiring diagram for a double-circuit car that has eight lamps inside, two headlights, and two tail-lights. The Westinghouse type of switch is selected on all the diagrams given here, because it is so much easier to follow the path of the current through it. When the **U** plug is in the two top holes, the headlight burns; when it is in the two bottom ones, the headlight is cut out and the tail lamp

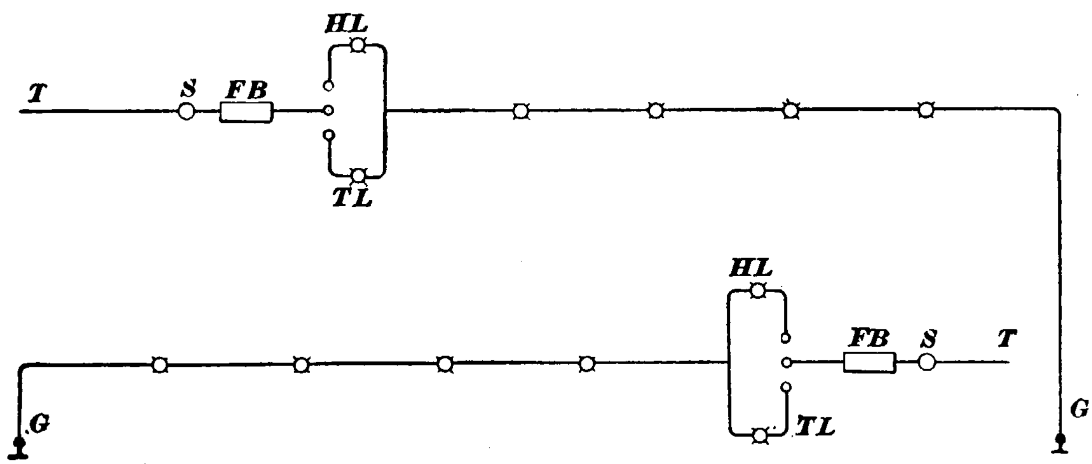

FIG. 51.

burns. *S* is the usual snap switch for cutting off the current. There is a ground wire and a trolley wire on both ends of the car, but there is no unbroken wire running the full length of the car. There is a snap switch and a three-way switch on each circuit, which may be put on the same end or on opposite ends of the car, as they are in the figure. If it is desired to control both circuits from the same end of the car, as shown in Fig. 52, two more wires must be run the full length of the car, in order to connect the three-way switch with the headlight and tail-light at the far end. The lamps inside the car are here shown in straight rows, though they may, of course, be grouped in any desirable manner.

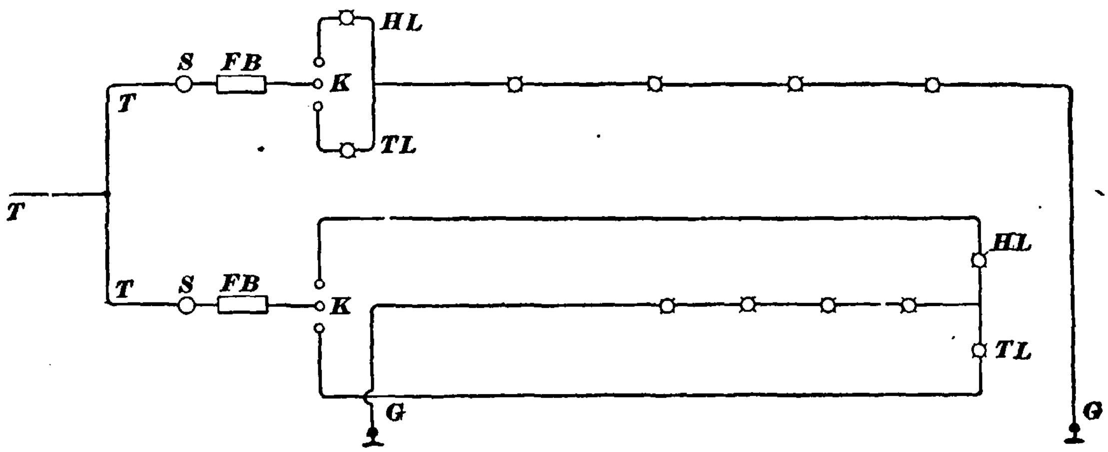

FIG. 52.

Switches *K* and *K* may be plugged so that both of the head-lights or both of the tail-lights will burn.

47. Fig. 53 shows one style of lamp wiring to be used on elevated or on converted steam roads, where not only are headlights needed, but markers as well. The markers are supposed to show a red, green, or white light, or some combination of the two, to indicate the destination of the train.

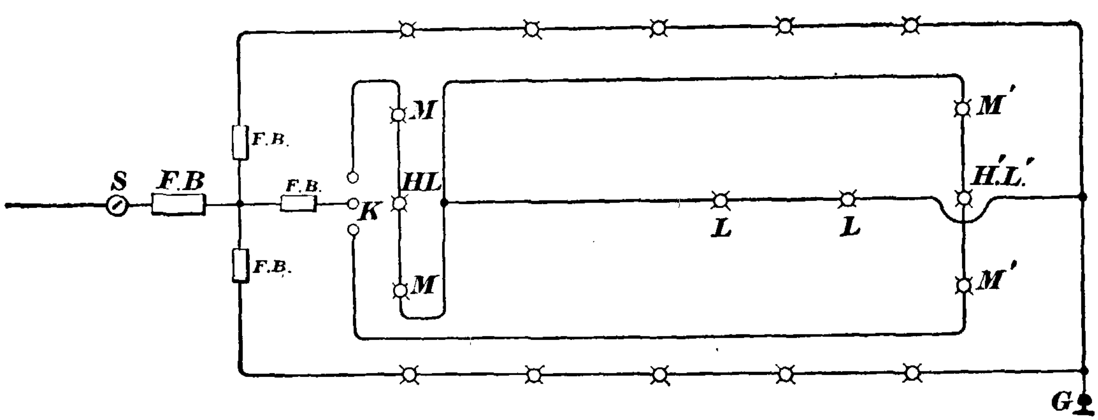

FIG. 53.

In Fig. 53, *M*, *M* and *H L* are the markers and headlight on one end of the motor car; *M'*, *M'* and *H' L'* are the same on the other end of the car. *L*, *L*, the two lamps inside of the car, are in the form of a two-light cluster, and burn whenever the signal lamps on either end of the car burn.

DASH LIGHTS AND HOOD LIGHTS.

48. In the wiring diagrams shown, the headlights have been placed on top of the bonnets of the cars; when so placed, they are spoken of as **hood lights.** But headlights are not always put on top of the hood; on many roads, they are set into a round hole cut in the center of the dash iron; when so placed, they are spoken of as **dash lights.** Fig. 54 gives a general idea as to how a headlight sets into the dash. The style shown is known as the **pot headlight.** *A* is the dash rail; *I*, the iron; *F*, the floor; *H L*, the headlight whose cover *C* swings outwards; *P*, an iron pipe, through which the wires are run to the lamp socket.

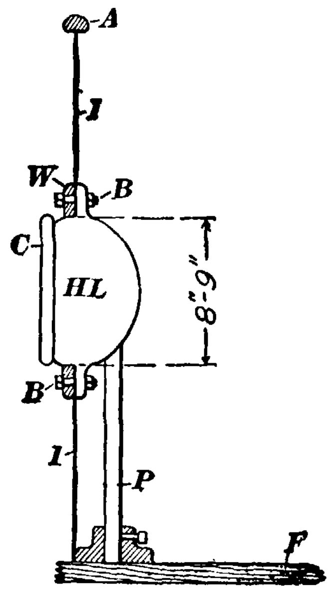

FIG. 54.

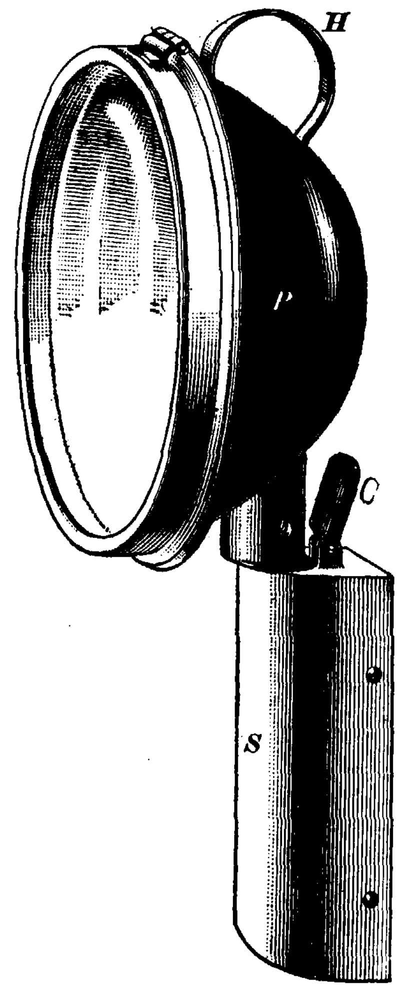

FIG. 55.

49. The dash light is not always set into a hole in the dash iron. There is one type of dash light, of which a large number are in use, that sets outside of the dash iron in a socket on the bump block. There is a socket on each end of the car and but one headlight is used on each car. When the car turns at the end of the road, the dash light, of course, stays on the same end; but if the car does not turn, the headlight must be drawn out of the socket on one end and dropped into the socket on the other end. In Fig. 55, *P* is the changeable part of the outfit; *S* is the socket or receptacle, which is a fixture on the car, and *C* is a cap or cover that is to be shut down as soon as *P* is drawn out of *S*.

50. Changeable-Headlight Wiring Diagram.—Fig. 56 shows how two interchangeable headlights are wired in a five-lamp circuit; the headlight, of course, has a lamp 7 of its own, and according as the headlight is on one end of the car or the other, lamps L_1 or L_5 are cut out and replaced by 7. In this figure, the headlight is in place on the right-hand end of the car and car lamp L_5 is cut out. The path of the current is *T–S–F B–1–2–3–4–*L_1–L_2–L_3–L_4*–5–6–7–8–9–10–G*. In the side of the tongue of the headlight that goes into the

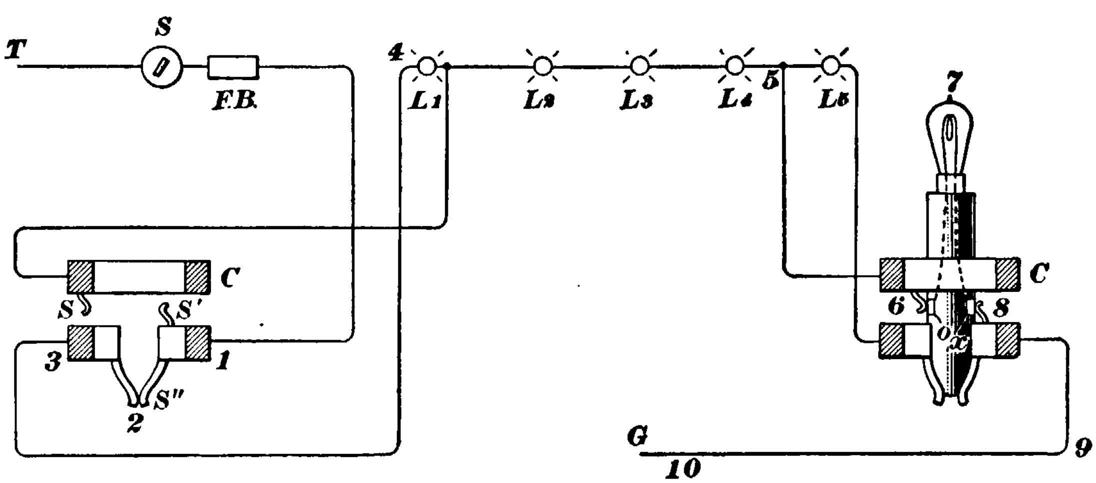

FIG. 56.

socket are two contact plates, shown at *o* and *x*, to which are connected the two wires from the posts of lamp 7. At *S* and *S'* are shown the two springs that make contact with these two plates when the tongue is shoved into the socket. Springs *S''* make a path for the current to go through when the headlight on that end of the car is not in place. As soon as the tongue is dropped into the socket, its end forces the two springs apart and the current flows through the headlight.

51. Changeable Headlight on a Two-Circuit Car.—Fig. 57 shows a light-wiring diagram for an interchangeable headlight to be used on a car that has two five-lamp circuits. The removal of the headlight from either end of the car

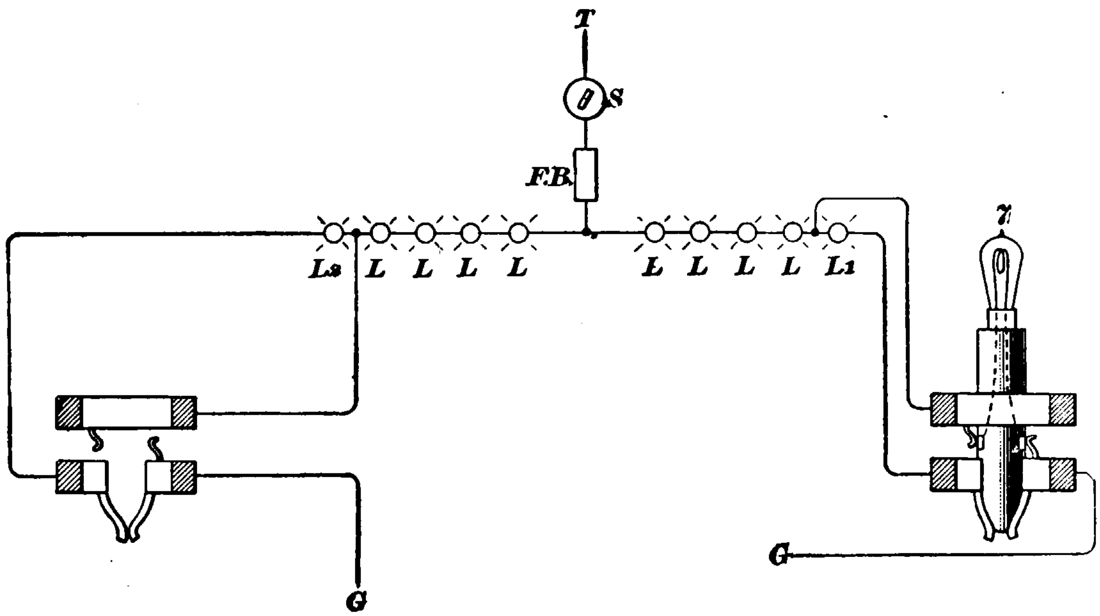

FIG. 57.

automatically cuts the fifth car lamp into circuit on that end to take its place.

BRAKES.

INTRODUCTION.

52. One of the most important items in the equipment of a car is the brake. Most of the cars in common use are equipped with **hand-brakes,** in which the brake shoes are forced against the wheels by a system of levers operated by the handle under the control of the motorman. The general tendency has been to increase the weight and size of cars, and hand-brakes have in many cases been found inadequate to control them. This has resulted in the introduction of **air brakes,** in which the shoes are pressed against the wheels by means of a piston connected to a series of levers; this piston is operated by means of compressed air. Another type of brake which as yet has not been used very extensively is the **momentum brake,** in