ELECTRIC-CAR EQUIPMENT

MOTOR-CIRCUIT APPLIANCES

TRUNK CONNECTIONS

1. By **electric-car equipment** is meant the several appliances by means of which the car is propelled, controlled, heated, lighted, and protected, as well as the system of wires necessary to connect the electrical devices. Some car equipments are more elaborate and complicated than others, due to widely different conditions of operation. To illustrate: on level roads employing small cars that run around a belt or loop, the car equipment may consist of a single controller, two motors, and hand-brakes; on other roads, where cars made up into trains must be accelerated to full speed and stopped in minimum time, the unit equipment may consist of four heavy motors with automatic devices for controlling the motive power, an elaborate system of high-speed automatic air brakes supplemented with air signals, and the most modern appliances for heating and lighting by electricity. The following discussion will be limited to a consideration of the average modern equipment, operated under ordinary conditions.

2. The **trunk connections** have to do with the wires and devices traversed by the motor current in its passage from the current collector—trolley wheel, third-rail shoe, or conduit plow, as the case may be—to the point or points where the main control device receives it for application to the motor circuit in various combinations. The motor ground connections are sometimes considered as part of the trunk system.

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TRUNK WIRE

3. The **trunk wire** is the wire part of the trunk connections, and takes its name from the fact that it conducts the total motor current of the car. It begins at the current collector and its path depends on the nature of the system on which the car is to be operated and on the location of the devices to be included. For example, Fig. 1 indicates the trunk wire on an ordinary surface car equipped with two hood switches and a fuse box; all devices are named and the current path is indicated by the order of the numbers. Fig. 2

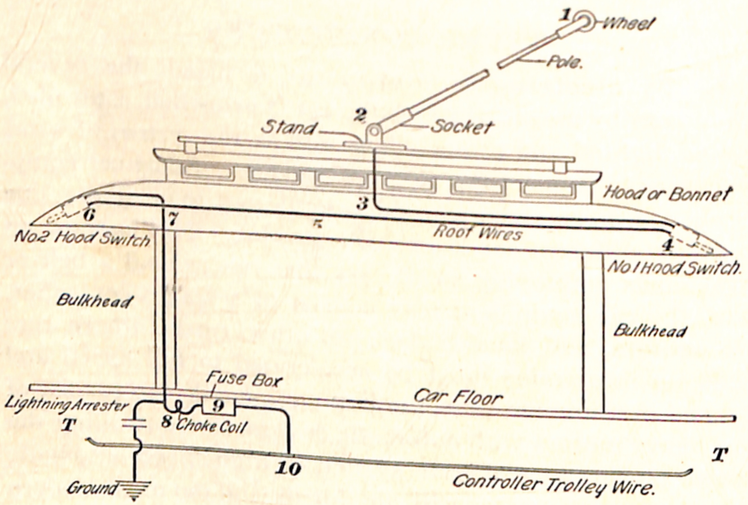


FIG. 1

shows the arrangement on cars intended to operate on both a third-rail and overhead ground-return system. The overhead construction includes two trolley stands, on opposite ends of the car, which may or may not be connected together; in either case a roof wire runs from each stand to a single-pole, double-throw, change-over switch in the vestibule or cab on that end. The third-rail construction consists of a spine wire running down the center of the under side of the car floor. The third-rail contact shoes on opposite sides of

the same truck are connected by a cross-wire that also connects to the spine wire, thereby connecting all four shoes together. A shoe is necessary on each side of each truck, because not only does the third rail contain gaps in places, but it frequently changes from one side of the track to the other. A car operating always from the same end on a road having a continuous contact rail always on the same side of the track would require but a single contact shoe. The continuation of the spine wire on both ends of the car is carried up through the bulkhead in some cases; in other cases, through metal conduit on the outside, to the other outside post of the change-over switch in the vestibule. From the handle post of the change-over switches the controller trunk wire runs to a circuit-breaker, located in the vestibule or under the car, and the other side of the circuit-breaker connects to the trolley post of the controller on that end. In some cases, a circuit-breaker or enclosed fuse is introduced in the spine-wire extension before it goes through the car floor, the idea being to have a safety device as near as possible to the contact shoes; but this idea is more often carried out by installing a fuse, called a *shoe fuse*, on the side of the truck above each contact shoe. The advantage gained by using the change-over switches is that the contact shoes of a car operating from the overhead wire are not alive. This is an important feature of safety at stations where passengers might come into contact with the third-rail shoes.

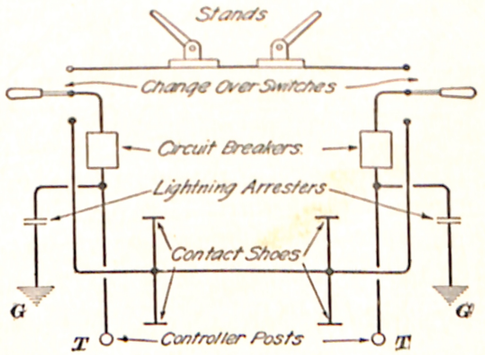


FIG. 2

4. Fig. 3 is a diagrammatic sketch of the trunk connections on a car equipped to operate on a conduit system. In this case, the trunk wire must traverse the distance from

the floor to the roof four times in order to reach the two overhead switches or circuit-breakers and return to the two controller trolley wires required in a metallic-return system. The bonnet switches are not necessary in this case, but are used to afford the motorman a convenient means of interrupting the current should the controller become disordered. On the open-conduit system, as operated in New York City, besides the motor switches installed in the bonnet there are installed under the car two circuit-breakers, two *ground switches*, so called because they were formerly the only means of cutting off the effect of grounds, and two fuses. All these devices are in series, so that the opening of any one of them will interrupt the current.

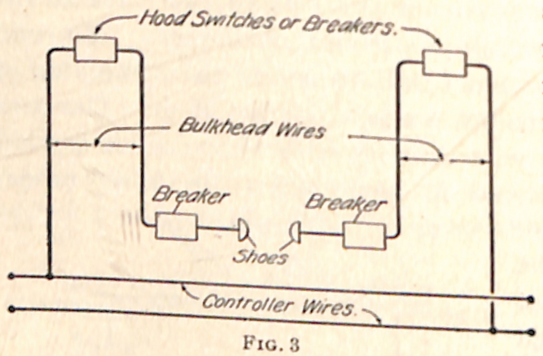


FIG. 3

OVERHEAD-TROLLEY FITTINGS

5. On ground-return overhead systems but one wire is used, so that short cars and long cars operating from the same end all the time require but one trolley device. Long cars that operate from both ends usually have two trolley devices, only one, however, being used at a time. On metallic-return overhead systems two trolley wires are used, thereby requiring a double, or duplicated, trolley device. On very long cars, there should be a double trolley device on both ends if the car operates from both ends.

The trolley device, or *trolley*, as it is commonly called, consists of a brass grooved *wheel* that turns on an axle supported in a suitable forked device, called a *harp*, that is riveted to the *trolley pole;* the pole being clamped in the *socket* of a *spring base* pivoted to a *foot* that is screwed to a board fastened to the car roof.

THE STAND

6. The Nuttal Stand.—Fig. 4 shows a type of trolley stand of which there are many in use. Base *a*, pivoted to foot *b*, which is let into the trolley board, carries an upright extension that serves as a bearing for axle *o*, around which socket *G* can rock in a vertical plane. Wings *f*, *f*, integral with the socket casting, engage tension rods *e*, *e*, of

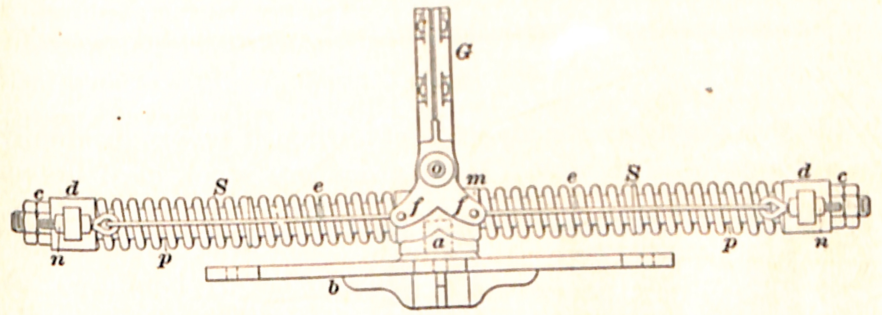
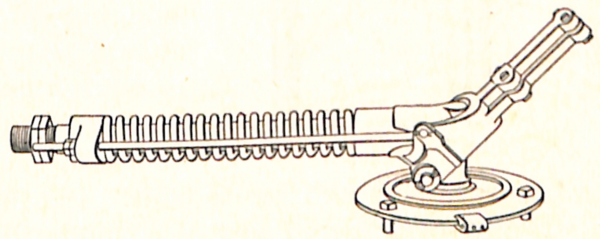


FIG. 4

which the other ends engage castings *d*. Movement of socket *G* in a clockwise direction will cause right-hand tension rod *e* to pull on its casting *d*, thereby compressing spring *S* mounted on right-hand arbor *p* and resisting the movement of the socket. Counter-clockwise movement of the


FIG. 5

socket will put the left-hand spring *S* into action. It follows, then, that if a pole under tension leaves the wire, the successive action of first one spring and then the other lessens the shock that the device would otherwise get.

7. The Union Stand.—Fig. 5 shows the union stand, which, having but one spring, cannot be rocked over. The

characteristic feature of this stand is that the same spring serves as a tension spring and as a recoil spring to take the shock when the wheel flies off the trolley wire.

POLE, HARP, AND WHEEL

8. Pole.—The pole proper, which is from 12 to 15 feet long, is about $1\frac{1}{2}$ inches in diameter at the large end, and



FIG. 6

holds this diameter for about 2 feet, when it tapers gradually to a diameter of 1 inch. Most poles are steel, hard drawn by a special 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 steel is generally such that the part heated becomes soft and easily bent. Fig. 6 gives an idea of the straight and tapered part of a standard pole.

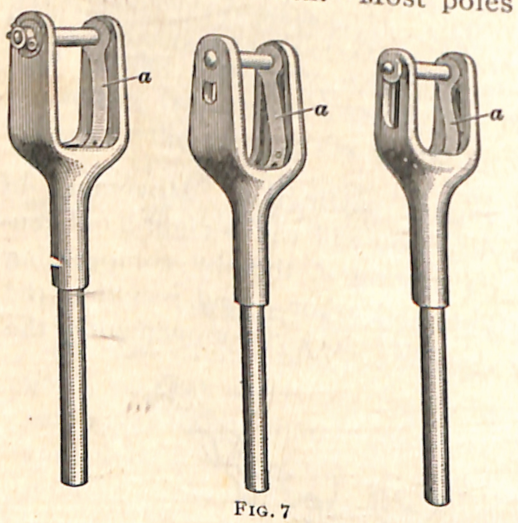


FIG. 7

9. Harp.—The harp in which the wheel turns is the forked device secured to the small end of the pole. Harps are made of malleable iron or brass and are of various sizes and shapes, depending on local conditions. Fig. 7 shows several styles of harp, all of which are provided with two springs *a*; the end of each spring bears against the side of the trolley wheel, thereby preventing the bearing surface

between the wheel and axle from carrying appreciable current. The main requirements of a harp are that it be as light as practicable and of smooth contour, to minimize the chances of its catching in the line work and pulling it down.

10. 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 more quickly than others, and some are harder on the trolley wire. 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 do a certain amount of experimenting to decide what shape and metal are best

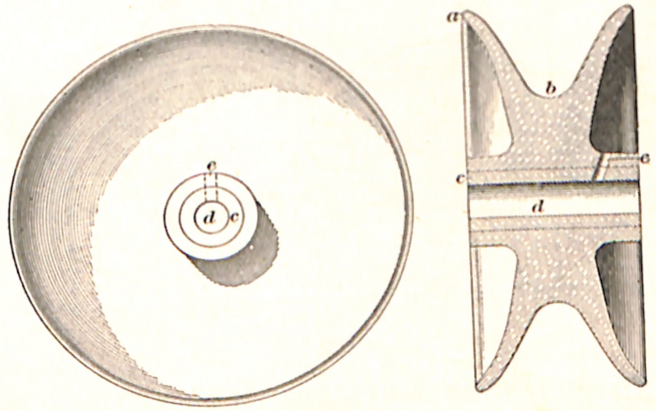


FIG. 8

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.

Fig. 8 shows a type of wheel, of which *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. On the more modern types of trolley wheel, of which a number are shown in Fig. 9, the bearings are of the self-lubricating type.

The diameter of trolley wheels varies from 4 to 8 inches, according to the speed of the service, the most common size being about $4\frac{1}{2}$ inches in diameter. The last of the series of wheels shown in Fig. 9 is called a **sleet wheel**, because it is used to cut sleet off the wire. The wheel is cast with holes in the flanges and the machining of the grooves leaves the holes with sharp edges that cut the sleet. In the absence of a sleet wheel it is customary to remove the ordinary wheel and use the harp as a cutter.

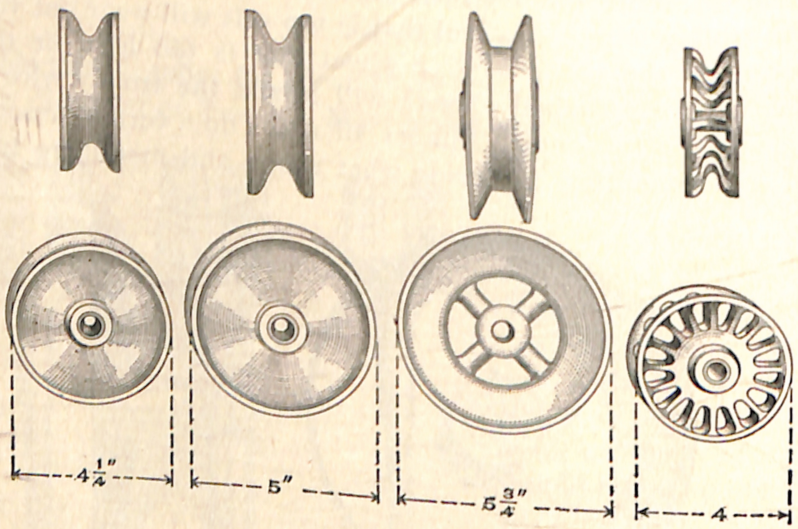


FIG. 9

11. Pressure of Wheel on Wire.—The pressure of the wheel against the trolley varies from 12 to 20 pounds, according to local conditions and the speed at which the car is to run. Too light a pressure will permit the wheel to jump off at kinks and turns, while excessive pressure will wear all parts unnecessarily and cause trouble in replacing a wheel that has jumped the wire. Under ordinary conditions, the pole should make an angle of about 45° with the car roof and the upward pressure on the wire should be about 15 pounds.

SWITCHES AND BREAKERS

SWITCHES

12. Remarks.—The motor switches used on cars to interrupt the motor circuit are of the same general type, whatever may be the nature of the system on which the car is to operate. On ground-return systems they are installed under the car hoods, and are called **hood switches.** In slotted conduit work the hood switches are also installed for reasons of safety, but in addition similar switches are installed under the car, as near as possible to the plow shoes.

13. Type of Switch.—Fig. 10 shows a motor switch in very general use; it is of the magnetic blow-out type.

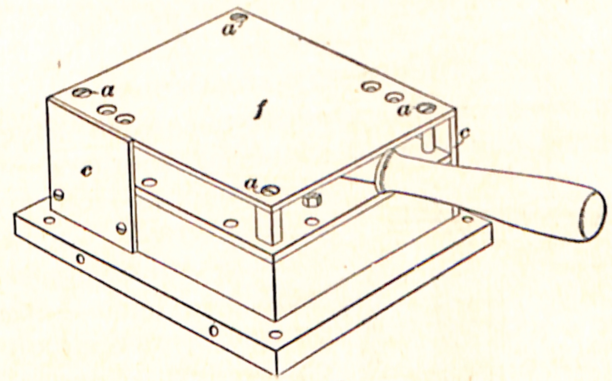


FIG. 10

Fig. 11 shows the top plate removed, exposing the connections. In Fig. 11, $e+$ is the roof wire leading to the switch and $e-$, that leading from it. The switch blade turns on pin p as a center, and M indicates the magnetic blow-out coil in the bottom of the case. Switch blade B is of iron and covers part of the magnetic circuit through which coil M sets up lines of force that pass across the current-breaking contacts. When the switch is closed, as in the figure, current enters at $e+$; to reach pin p, part of the current passes from the terminal jaw a through the switch blade, and part passes through coil M, which is of very low resistance. The

total current passes through the right-hand end of blade *B* to reach jaw *d*. On opening the switch, the instant jaw *a*

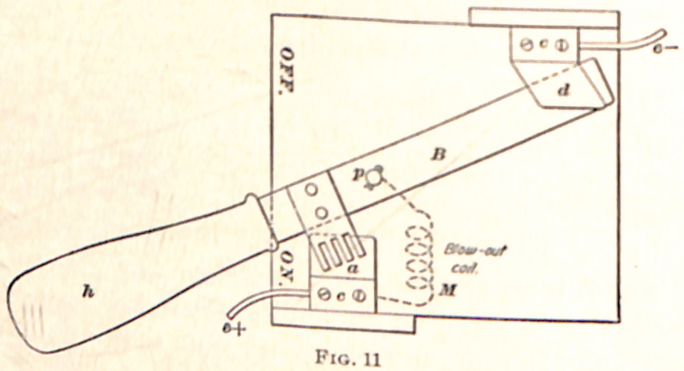


FIG. 11

breaks contact with the switch blade, the entire current must pass through blow-out coil *M*, thereby establishing a strong magnetic field that ruptures the arc at *d*.

CAR CIRCUIT-BREAKERS

14. In some cases, **circuit-breakers** have entirely replaced hood and ground switches; in others, one of the two hood switches has been replaced by a circuit-breaker; while in still others, two ground switches have been supplemented by two circuit-breakers connected in series with the switches and located alongside of them. All car circuit-breakers have facilities for operating them by hand, like a switch, and the only advantage of using a circuit-breaker and motor switch in series is to obtain the automatic safety feature of the breaker without buying two breakers. Car circuit-breakers should always be adjusted in the position that they are to occupy when on the car, otherwise gravity may introduce an error in the setting.

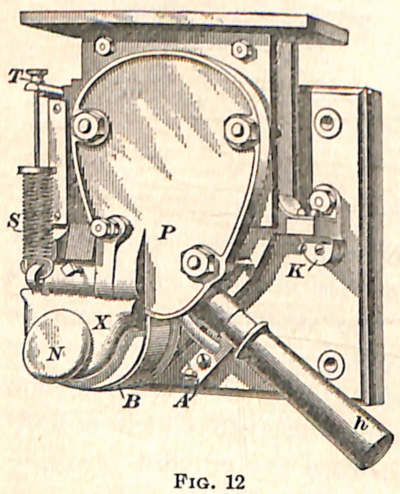


FIG. 12

15. General Electric Car Circuit-Breaker.—Fig. 12 shows a type of surface-car circuit-breaker made by the General Electric Company. When used as a hood breaker it is enclosed in a box from the front end of which the handle projects, as indicated in Fig. 13.

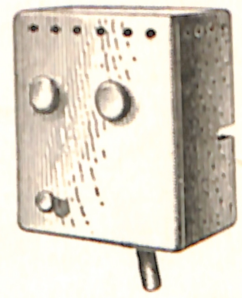


FIG. 13

In Fig. 12, *A* and *K* are the breaker terminals and *B* the operating coil, which also provides magnetism for extinguishing the arc. Coil *B* pulls armature *X* against spring *S* whenever the current exceeds that for which the breaker is set. The operating current value is adjusted by means of nut *T*. The iron

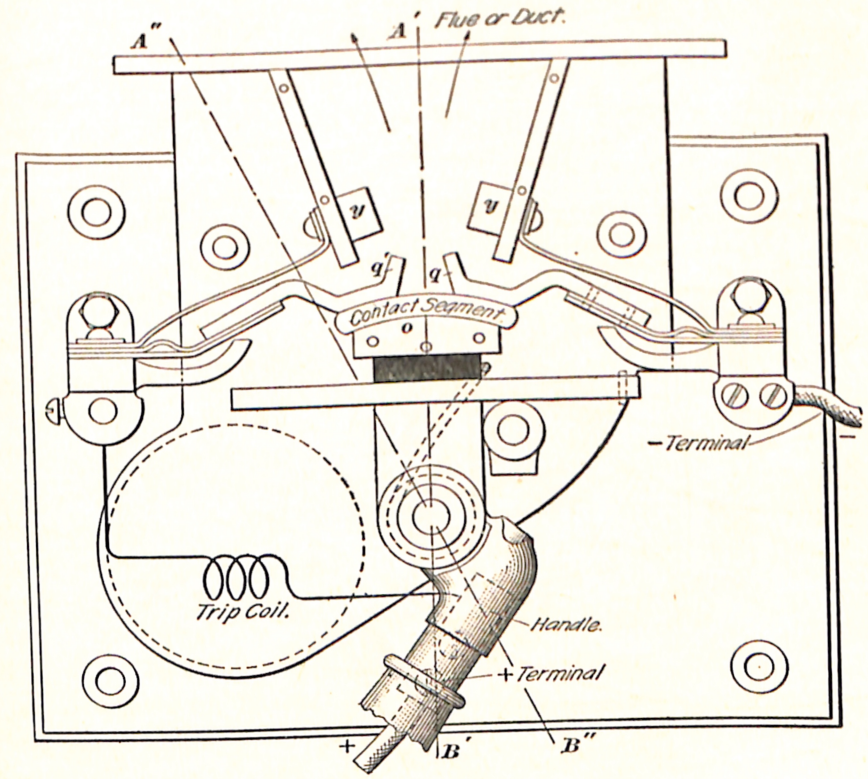


FIG. 14

plate *P* and a similar one back of it are magnetized by the current in coil *B*, and as the arc occurs between these two

poles, it is promptly extinguished by the magnetic field existing there.

Fig. 14 shows the movement of parts during operation of the breaker. The contact segment engages fingers q, q', so that the breaker is closed. When the breaker operates, the center of the contact segment o takes a position coinciding with line A'' B'', thereby leaving an open circuit between fingers q, q'. The arc is forced up by the magnetic field to auxiliary contacts y, y, between which it is broken without damage.

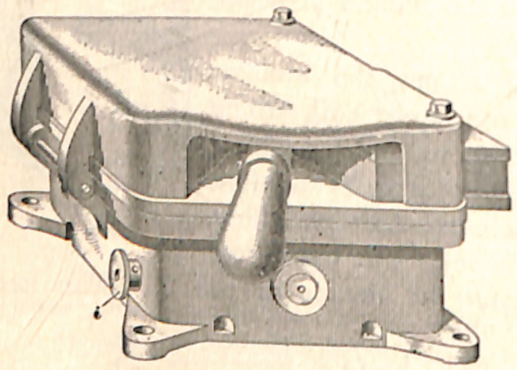


FIG. 15

16. Westinghouse Type of Car Circuit-Breaker. Fig. 15 is a general view of a surface-car breaker made by

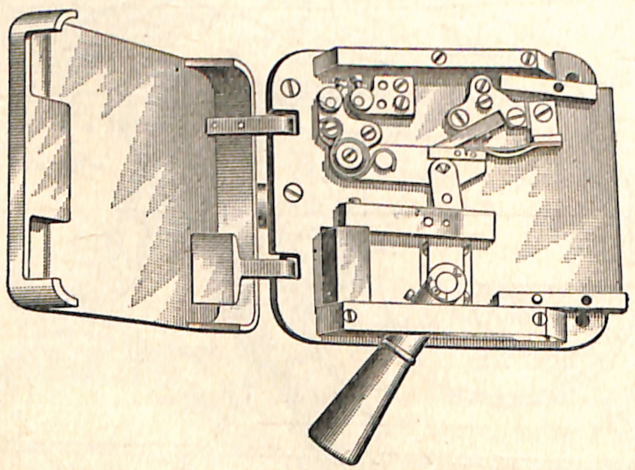


FIG. 16

the Westinghouse Company. The screw for adjusting the operating current value is shown at i; this screw must be pulled out a little and turned while it is held out, in order to

adjust the tension on the spring that regulates the tripping point. Fig. 16 shows the breaker with the circuit-breaking parts exposed, and Fig. 17 indicates the movement of the circuit-breaking parts from the on- to the off-position. When handle a is to the left, the breaker is held closed, because spring l keeps togglejoint cd beyond the dead center, but no further than permitted by a projection on the under side of slide f.

To operate the breaker by hand, handle a must be forced to the right, thereby bending the togglejoint to the left and permitting spring l to snap blade e and all attached parts to the dotted position. Automatic operation is effected by an electromagnet, the coil of which is energized by the current and pulls armature g to the left, thereby bending the togglejoint to the left, as in the case of hand operation, whenever the current exceeds the value for which the breaker is set. The secondary contacts o and p are in parallel with the primary contacts m, n when the breaker is closed. When the breaker operates, m leaves n before o leaves p, thereby breaking the current at contacts o and p, which are cheap and easily replaced. The final break takes place in a powerful magnetic field that promptly extinguishes the arc.

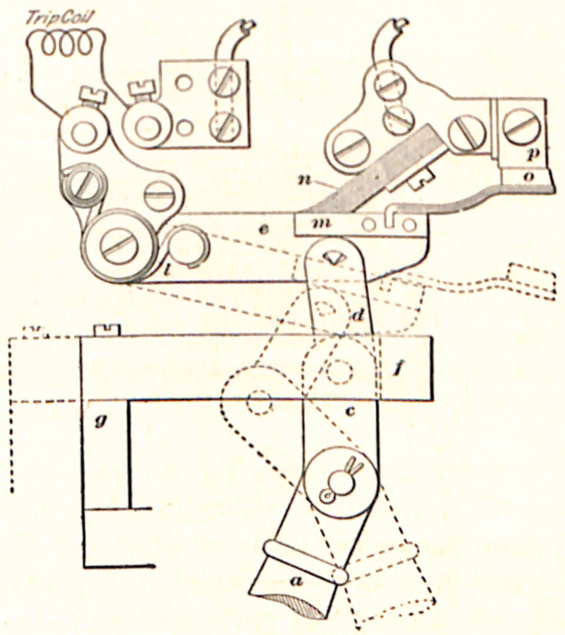


FIG. 17

FUSES

17. At one time, the fuse alone was used to protect motor circuits from excessive currents. On many roads, the circuit-breaker has superseded the fuse, because, for protection under given conditions, a circuit-breaker can be set to act at a closer overload value with a fair degree of certainty than a fuse; and in cases of operation, it is much easier and quicker to close a breaker than to replace a fuse. Circuit-breakers kept in proper repair and adjustment are certainly more reliable than fuses, from the protection point of view.

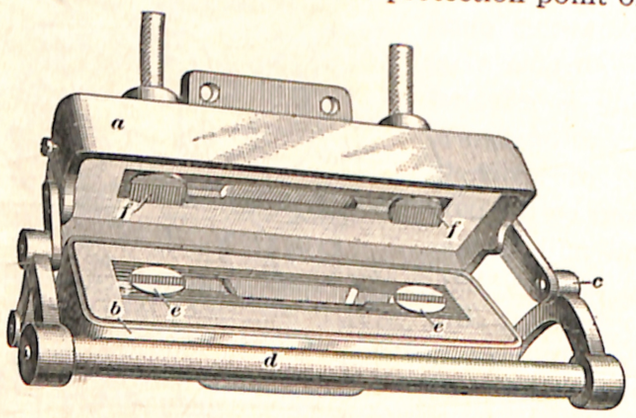


FIG. 18

On some large roads there seems to be a tendency to revert to the practice of using fuses, at least in conjunction with circuit-breakers, because in many cases of failure of the circuit-breaker the controller has blown up with disastrous results, as regards suits for damages. A circuit-breaker in series with a fuse is a good combination on a car, as the breaker is normally more of a protection than the fuse, but the fuse will prevent accidents should a short circuit occur and the breaker fail to operate because of being stuck.

WESTINGHOUSE CAR FUSE

18. Fig. 18 illustrates a type of fuse box introduced by the Westinghouse Company. The asbestos-lined iron box is divided into two parts *a* and *b*, hinged together through a

togglejointed construction *c* provided at the front with the handle bar *d*, the raising of which brings the two halves *a*, *b* together. In the bottom half are copper terminals with V-shaped grooves *e*, into which a piece of copper-wire fuse of suitable length is dropped. Registering with the V-shaped grooves *e*, *e* in the bottom terminals are V-shaped tongues *f*, *f* in the top terminals. On bringing the top and the bottom halves of the case together, by pulling up handle bar *d*, the two pairs of V-shaped jaws automatically clamp the fuse in circuit. The advantages of this type of fuse box are low maintenance cost and the care and quickness with which a fuse can be replaced without liability of shock; the lower terminals are dead when the case is open.

The size of copper wire to be used as a fuse to protect any equipment of given horsepower can be obtained as follows:

Rule.—*Multiply the total horsepower of the equipment by 70, and in the circular-mils column of any wire table find the nearest number to the product so obtained.*

EXAMPLE.—What size of copper wire must be used to protect an equipment of two 50-horsepower 500-volt railway motors?

SOLUTION.—The total horsepower of equipment is $2 \times 50 = 100$. $100 \times 70 = 7{,}000$. The nearest number to 7,000 in the circular-mils column of a B. & S. wire table is 6,529, which corresponds to a No. 12 B. & S. wire. Ans.

ENCLOSED FUSES

19. Figs. 19 and 20 illustrate fuses that, on account of the fuse metal being enclosed, are called **enclosed fuses.** The hollow cartridge *a*, Fig. 19, is made of some tough, fibrous, insulating material and is provided with copper heads or terminals *b*. The fuse metal occupies the hollow space, and its two ends connect to terminals *b*; the space surrounding the fuse is filled with finely divided powder, such as plaster of Paris mixed with powdered borax, which, when the fuse melts, fluxes with the molten metal, rendering it non-conducting and preventing the formation of an arc. The fuse as a whole is installed in spring jaws *c*, connected with terminals *d*, by means of which the fuse is connected

in the circuit to be protected. In Fig. 19, the parts are simply mounted on a slate base, but in Fig. 20 the whole device is enclosed in an asbestos-lined iron box *a*, provided with a lid *b* held closed by latch *c*. The trunk wire passes to

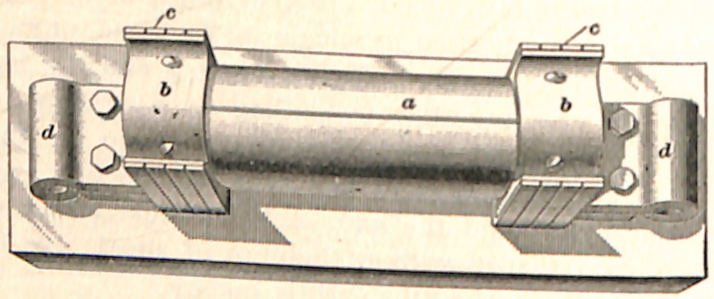


FIG. 19

fuse-block terminals *d* through hollow insulating bushings *e*. Some enclosed fuses, instead of having contacts to fit spring jaws, have ordinary eye terminals that must be secured to their seats with screws. The screw connection is probably

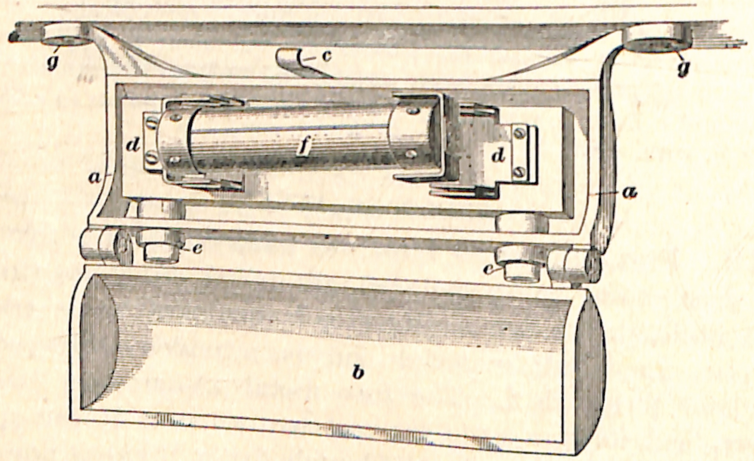


FIG. 20

more mechanical, but the spring-jaw construction is sufficiently safe and is much more convenient.

To tell whether or not the enclosed fuse is blown, a small wire *f*, called the *telltale*, is connected in parallel with the

enclosed fuse but on the outside of the cartridge. When the main fuse blows, the telltale burns out also. The enclosed type of fuse can be installed without danger of burn or shock, by taking hold of the cartridge at the middle.

LIGHTNING ARRESTERS

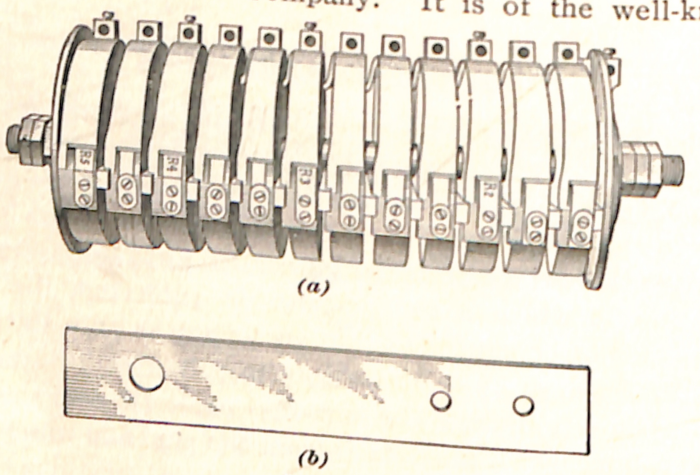
20. Lightning arresters used in car work are practically the same as many of the arresters described in a preceding section. A car arrester must have facilities for extinguishing the arc due to the line current following the lighting discharge across the gap. Owing to the jolting and vibration to which a car arrester is subjected, the spark points cannot be set for as thin an air gap as on a stationary arrester, because of their liability to jolt together and produce a short circuit. The arrester must be enclosed in a wooden box, which protects it from the mud and water slung by the car wheels.

On cars that operate entirely in a tunnel or on a conduit system, no arresters are needed on the car, but exposed line feeders are protected in the usual manner; this is also the case on elevated third-rail systems. On overhead metallic-return systems, both ends of the motor circuit must be protected by an arrester. On ordinary surface trolley cars but one arrester is used on the trolley end of the motor circuit; two would be better as a factor of safety should one get out of adjustment.

An arrester having parts depending on gravity for action should be installed vertically, otherwise it cannot work. Where an external choke coil is used, or an arrester has three terminals, one of which leads to an internal choke coil, care must be taken to connect the arrester so that the choke coil is in series with the motor circuit and not in series with the air gap.

RESISTANCE COILS

21. Westinghouse Starting Coil.—Fig. 21 illustrates a type of car **resistance coil**, or so-called **diverter**, made by the Westinghouse Company. It is of the well-known



(a)

(b)

FIG. 21

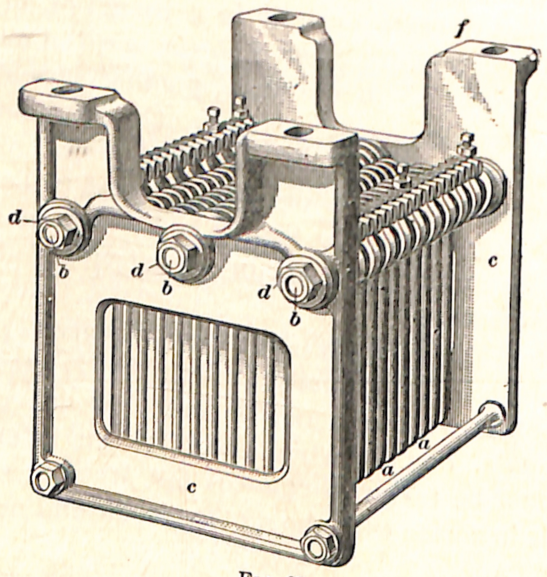


FIG. 22

barrel type wound with band iron, with mica insulation between layers. It is a decided improvement on older types in that the ventilation facilities are much better, on account of

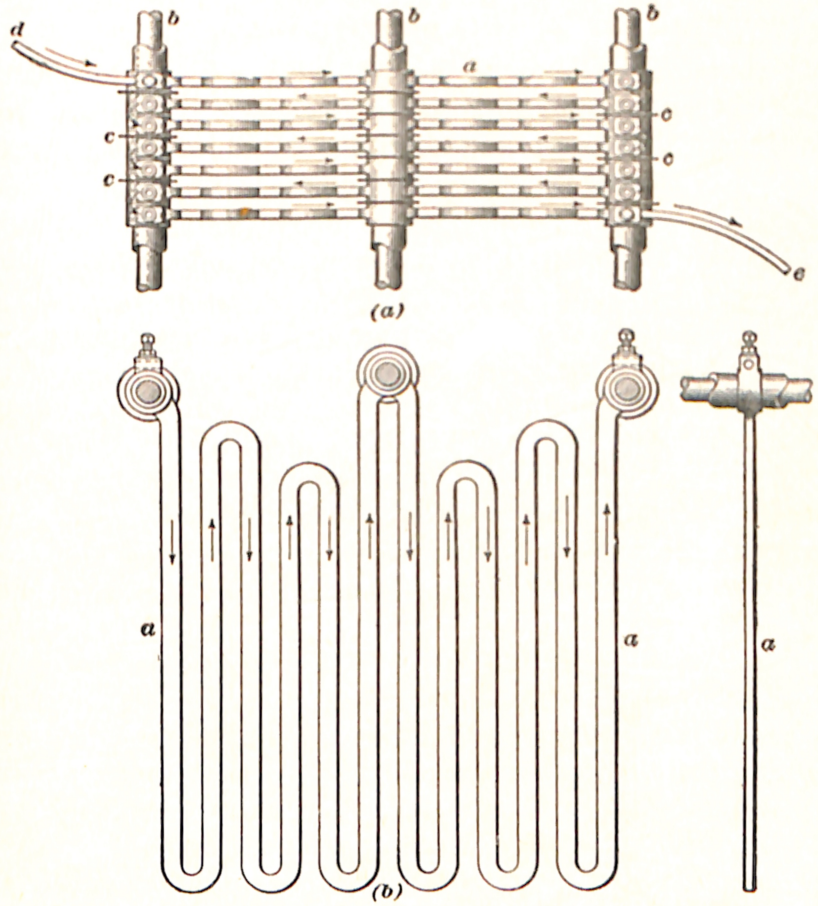


FIG. 23

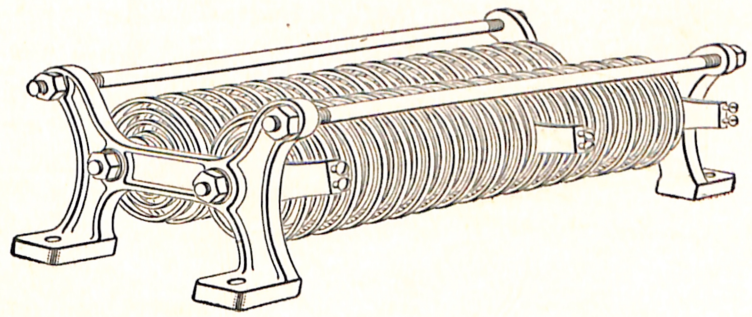


FIG. 24

an air space being left between the sections of the winding; (*a*) shows the coil and (*b*) one of the iron hangers used for suspending the coils from the car sill.

22. General Electric Grid Coil.—Fig. 22 is a view of the General Electric type of **grid coil**, of which Fig. 23 (*b*) shows the shape of the cast-iron grid and (*a*) the zigzag path of the current through the grids. The grids *a*, *a* are assembled on insulated studs *b*, *b*, end plates *c*, *c*, Fig. 22, being then put on and the whole compressed into a solid mass by drawing up on nuts *d* at both ends. Feet *f* are for hanging the coil from the car floor. On the middle stud *b*, Fig. 23 (*a*), all the grids are separated from each other by mica insulating washers. On the two outside studs *b*, however, considering any two adjacent grids, they touch each other on one stud, but on the other stud they are separated by a mica washer.



FIG. 25

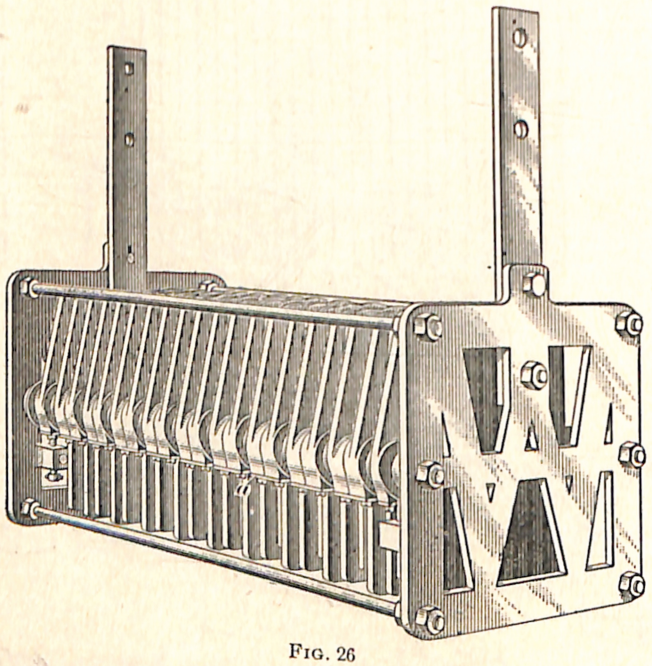


FIG. 26

The current entering at one end is thus compelled to take a zigzag path to the other end, as shown by the arrows. The

coil shown represents the unit starting coil used in heavy traction work, a complete starting coil of any desired capacity being composed of the required number of unit starting coils connected in series or parallel, or both. The coil used for surface trolley-car work is of the same construction, but is longer and may contain several sizes of iron.

23. Lundie Grid Coil.—Fig. 24 is a general view of the **Lundie grid coil**, and Fig. 25 shows the shape of grid used. The method of assembly is the same as that of the General Electric, except that contact between adjacent grids is improved by inserting a soft copper washer between them.

24. Westinghouse Grid Coil.—Fig. 26 is a general view of the grid coil. The general method of assembly is the same as that of the preceding examples, with the exception that adjacent grids are connected by means of a brass plate screwed to both of them, as shown at *a*.

CAR-WIRING REQUIREMENTS

25. Strictly speaking, the name **car wiring** includes all wires necessary to the operation of a car, but it is generally understood to apply only to the wires that interconnect the controllers, motors, resistances, and the ground; that is, the wires and dependent taps included in a consideration of the wiring cable of an ordinary car. The connections of the heaters and lamps are referred to independently as the heater wiring or the lamp wiring, while the stretch of circuit extending from the trolley stand to the controller trolley wire is referred to as the trunk wiring. On cars of moderate weight, it is customary to run the wires in a canvas hose or in conduit extending from one controller to the other, the hose being slit at intervals to let out taps that connect the several car wires to their respective controlling, operating, or safety devices. On heavy cars involving the use of large currents, the car wires are not bunched together in a hose, but are run separately on a smooth insulated surface, specially prepared for them, if necessary, and afterwards covered with specially molded insulation.

Fig. 27 illustrates a molded insulation, called *electrobestos*, used for this work. In ordering such expensive insulation, great care must be taken to get a correct plan of the proposed layout of the car wires, for mistakes in regard to it will be expensive. The car for which the samples of electrobestos shown were made had its under surface prepared within the working area by laying a sheathing of hard maple, this wood being comparatively free from acid; nailed

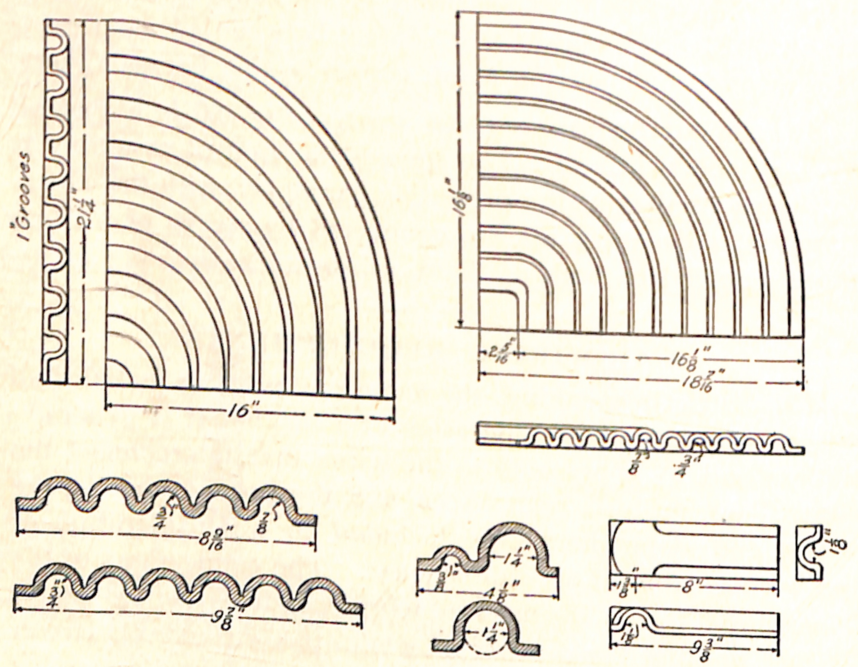


Fig. 27

to the maple sheathing was a ¼-inch layer of *transite board*, another special insulation not affected by water. After the installation of the transite, all nails passing through it were tested for insulation to see that they touched no grounded part. The molded type of insulation is specially adapted to those equipments on which all main-motor wires can be kept under the floor, the area to be insulated being there more congested and limited than on equipments employing platform controllers.

26. The following abstracts from the rules of the National Board of Fire Underwriters emphasize the importance of taking every practicable precaution to minimize the fire risk when installing car wiring, and thereby incidentally minimize the chances of operating troubles.

On cars equipped with motors of over 75 horsepower each, the under side of the car body should be lined with at least ⅛-inch approved insulation material or sheet iron or steel $\frac{1}{26}$ inch in thickness, extending 8 inches beyond all edges of motor openings, resistances, and other electrical apparatus not amply protected by the containing case. All conductors must be stranded and joints must be so spliced as to be both mechanically and electrically secure without solder, then soldered and covered with insulation equal to that on the conductor. All cut-outs and switches having exposed live metal parts are to be located in asbestos-lined cabinets. Cut-outs and switches not in iron boxes or in cabinets must be mounted on not less than ¼-inch fire-resisting insulating material, which must project at least ½ inch beyond all sides of the cut-out or switch. A cut-out switch must be placed as near as practicable to the current collector so that the opening of the fuse in this cut-out will cut off all current from the car. All conduits where exposed to dampness must be water-tight. All junction and outlet boxes must be so installed as to be accessible. Joints in molding must be mitered to fit close, the whole material being firmly secured in place by screws or nails and treated inside and out with waterproof paint.

27. The current used in determining the size of trolley, motor, and resistance leads is taken as a percentage of the full-load current, as given in Table I.

Table I is to be used in conjunction with Table II, taken from the Underwriters' table of carrying capacity of rubber-covered wires.

Suppose that it is required to determine the size of trunk wire to be used with an equipment of four 50-horsepower motors. The total horsepower is 200, corresponding to a

current of 300 amperes at 500 volts. From Table I, the size of wire is to be based on 40 per cent. of the current. $.40 \times 300 = 120$ amperes. From Table II, the allowable size for 120 amperes is No. 0 B. & S., having a cross-section of 105,500 circular mils.

TABLE I

Size of Each Motor Horsepower	Motor Leads Per Cent.	Trolley Leads Per Cent.	Resistance Leads Per Cent.
75 or less	50	40	15
Over 75	45	35	15

TABLE II

B. & S. Gauge	Amperes	Circular Mils
8	33	16,510
6	46	26,250
5	54	33,100
4	65	41,740
3	76	52,630
2	90	66,370
1	107	83,690
0	127	105,500
00	150	133,100
000	177	167,800
0000	210	211,600

The size of *motor leads*, by which is meant the size of wire running from each motor terminal, is obtained as follows: The full-load current of each motor is 75 amperes; from Table I, 50 per cent. of 75 amperes is $37\frac{1}{2}$ amperes; from Table II, the wire to be used is No. 6 B. & S.

ELECTRIC-CAR-HEATING APPLIANCES

ELECTRIC HEATERS AND CONNECTIONS

28. All **electric-car heaters** are made on the principle of forcing sufficient current through a resistance to heat it. A case keeps the feet and clothing of passengers from the hot wire. According to the size of car and the make of heater, four, six, eight, ten, twelve, or even twenty 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 is between 6 and 7 horsepower per car. Therefore, it costs considerable to heat a car by electricity, and when the heaters are in use there is quite a large 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 heaters are extensively used, even though they are more expensive to operate than coal stoves. They are nearly always installed in such a manner that at least three degrees of heat can be obtained by operating a **heater switch**, which changes the connections of the heaters.

The number of makes and styles of heaters is large, and it would be out of the question to treat all of them here. One or two typical examples will be described, however, in order to illustrate the method of connecting, which is practically the same for all makes.

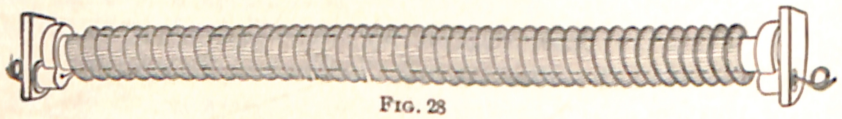


FIG. 28

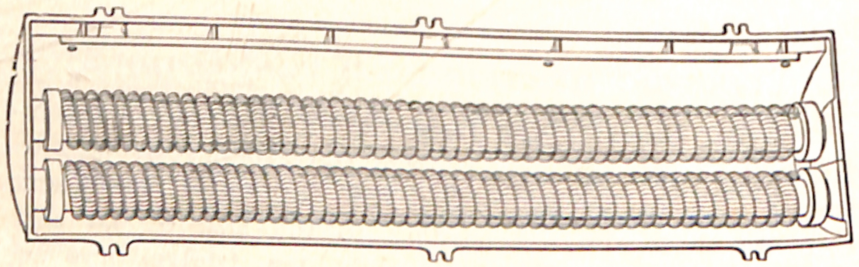


FIG. 29

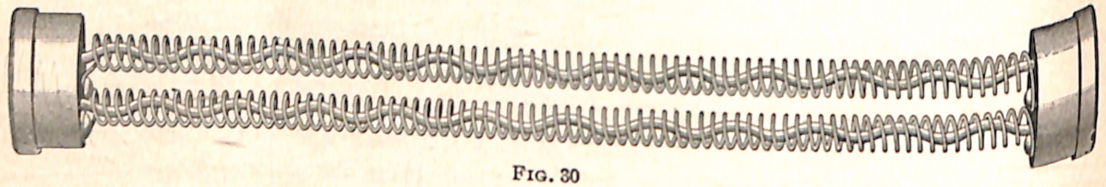


FIG. 30

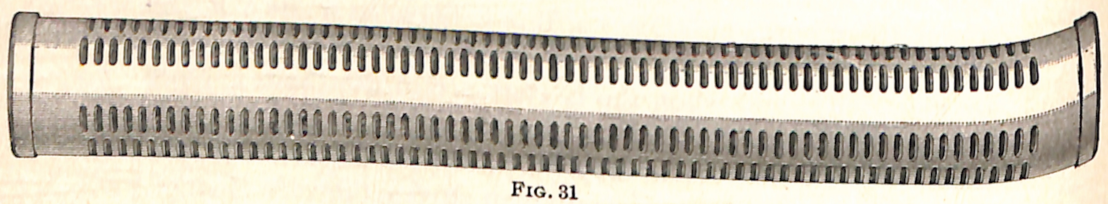


FIG. 31

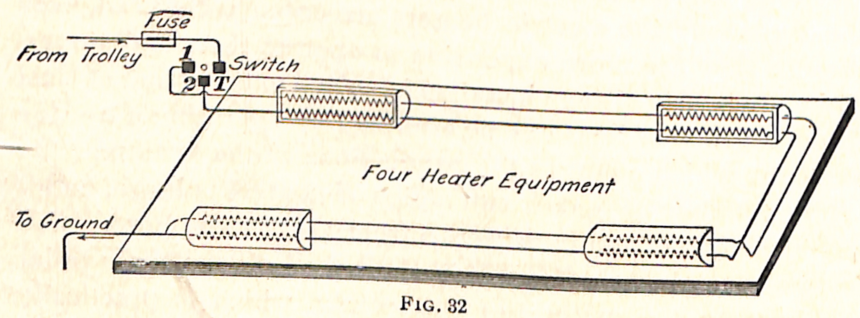


FIG. 32

TYPE OF PANEL HEATER

29. Fig. 28 shows the coil used in a standard type of car heater made by the Consolidated Car Heating Company and constructed as follows: On a stout rod are strung porcelain tubes that run the full length of the heater. These pieces have a spiral groove made continuous the full length of the core by the manner in which the porcelain-tube sections are placed on the rod. The heater coil is placed in this groove and a large amount of wire is thus placed in a limited space in a manner that admits of free circulation of air. The terminal wires that run out of the case at each end through porcelain bushings are attached to the ends of the coils 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. 28, placed one above the other, as indicated in Fig. 29, which represents a heater with the front plate removed to show the two coils in place. The type illustrated is for a side-seated car, and is intended to be set into a rectangular hole cut in the seat panel. Similar but shorter coils are adapted to cases of cylindrical form to be installed under cross-seats.

Fig. 30 shows the style of coil and the method of mounting it in the cylindrical type of heater made by the Gold Car Heating Company. Fig. 31 shows the Gold cylindrical heater complete.

HEATER-WIRING DIAGRAM

30. All electric-heater systems employ practically the same method of connecting the heaters and regulating the heat. Each heater has two independent coils, one of higher resistance than the other. Fig. 32 shows the heater wiring for a set of four Consolidated heaters controlled by the heater switch illustrated in Fig. 33. All top sections of the heaters are connected in series and all bottom sections are similarly connected. The negative ends of both sections of the last heater are grounded, on a ground-return system, or permanently connected to the negative conductor of a

metallic-return system. The positive ends of the two series of sections are so connected to the heater switch that on the first position of the handle all top sections are in series across the line; on the second position, the top sections

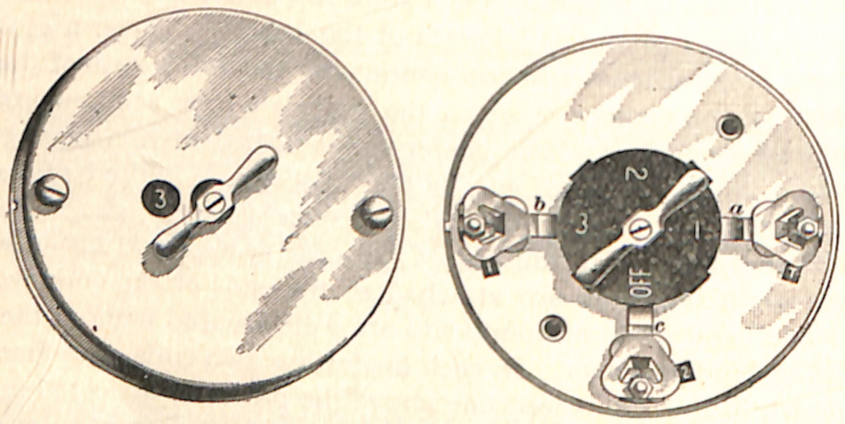


FIG. 33

are cut out but the bottom sections are in series; on the third position, the top and bottom sections are in parallel with each other, thus giving the greatest degree of heat obtainable with the given heaters. On the off-position of the heater switch all current is cut off.

OTHER SYSTEMS OF HEATING

31. Other devices than electric heaters are used for heating electric cars. Among them are the stove, hot-water system, and a system whereby the heat generated in the starting coil of the car is utilized. The main objection to electric heaters is the cost of the energy required by them, being more than one-third of that required to propel the car. The objections to stoves are the dirt that they make and the space occupied.

In the **hot-water system** of heating, the water flows through a closed circuit of heat piping including a pipe spiral contained in a firebox at one end or at the center of the car. The main objection to the hot-water system is the liability of

freezing unless the cars when not in use are kept fired or are laid up in a heated car house.

The **starting-coil heating system** is a feature of the combination traction brake and heat system of the Westinghouse Traction Brake Company. Resistance coils inside the car absorb the waste energy incident to starting and to generation of current by the motors when utilizing the traction brake. In warm weather such an arrangement would not be desirable, so that provision is made for then using the customary starting coil located under the car.

ELECTRIC-CAR LIGHTING

INCANDESCENT LIGHTING CIRCUITS

REMARKS

32. The **incandescent lighting circuits** on a car include the interior incandescent lamps, the rear platform lights of a surface trolley car, and possibly a hood or dash headlight, together with the facilities for changing over one or more lamps when the operating end of the car is changed. On cars to be made up into trains, there must be facilities for lighting both platforms on all but the forward car, which will probably also require signal lights, or markers, on the bonnet in addition to the headlight on the hood; and there must be change-over switches with which to change the headlight, markers, and platform lights to suit local conditions. In addition to lighting the car, the lamp circuit, when in good condition, is an indication as to whether the line is alive or not and as to the condition of the voltage.

EXAMPLES OF INCANDESCENT LIGHTING CIRCUITS

33. Fig. 34 shows a form of change-over switch that accomplishes the same result as the plug shown in Fig. 35. Both are used to cut one lamp out of circuit and cut another

in its place, as indicated in Fig. 36, which shows about the simplest arrangement of lamps for a car that must operate from both ends and always have a headlight and a rear-platform light. With the two plugs or switches in the full-line positions of the diagram, a headlight HL burns on both ends; with both plugs or switches in the dotted-line positions, a platform light PL burns on both ends. To get a headlight on one end and a platform light on the other, one switch or plug must be in the full-line position and the other in the dotted-line position.

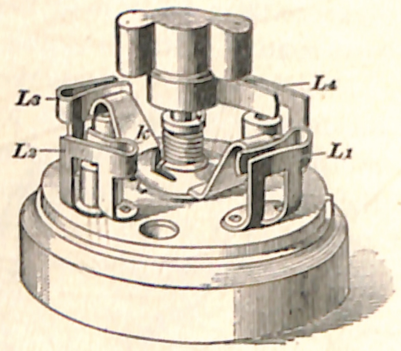


FIG. 34

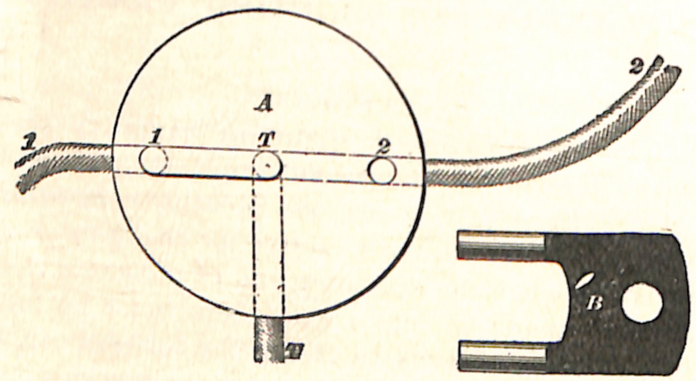


FIG. 35

34. Fig. 37 shows a plan of wiring for an elevated car employing both headlights and markers; the markers are

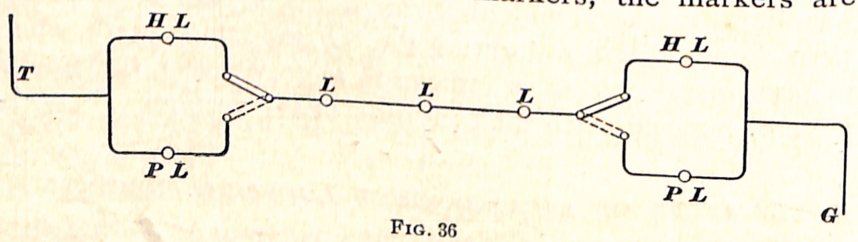


FIG. 36

intended to indicate the destination of a train. M, M and HL are the markers and headlight on one end of the

car and M', M' and H' L' those on the other end. L, L, the two lamps inside the car, light whenever the signal lights on either end of the car are in use.

35. Fig. 38 is the lamp-circuit wiring for an interchangeable dash light wired in a five-lamp circuit; the headlight, of

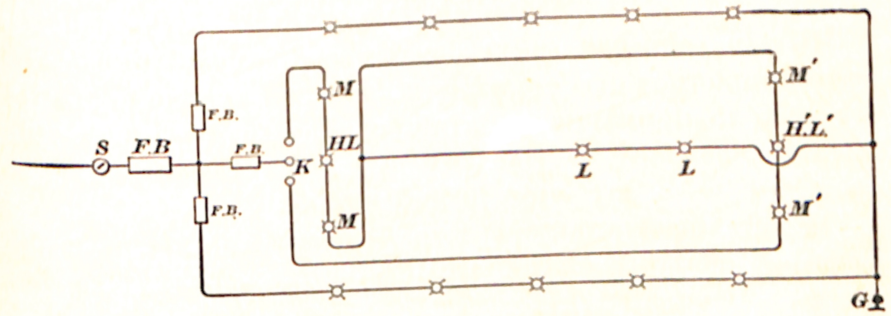


FIG. 37

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

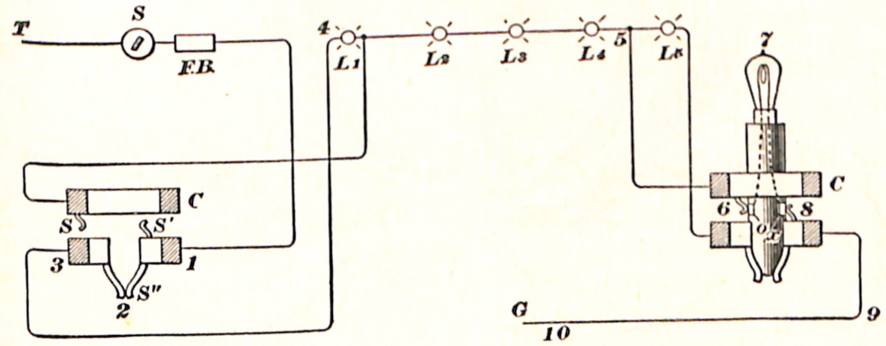


FIG. 38

is cut out. The path of the current is *T–S–FB–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 that slides into the 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, S' are shown the springs that make contact with these two plates when the tongue is forced into the

socket. Springs S'' make a path for the current 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.

ARC HEADLIGHT CIRCUIT

36. In suburban service, where cars run at high speed across numerous grade crossings, powerful **arc headlights** are used to illuminate the right of way for a considerable distance ahead of the car. In city work, the strong light projected by an arc lamp is undesirable.

Fig. 39 is a general, and Fig. 40 a sectional, view of the Crouse-Hinds combination arc headlight, which is provided

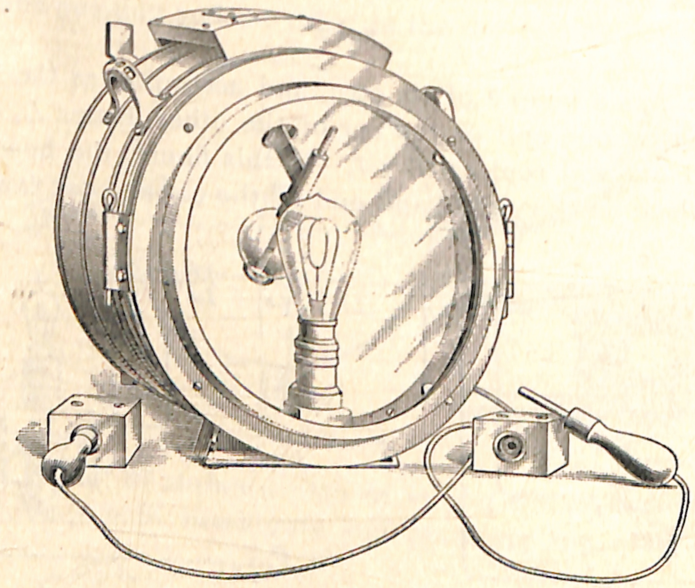


FIG. 39

with an incandescent light attached inside the door so that for city work the smaller light can be used. The arc-light carbons are inclined at an angle of 45° with the perpendicular, to present a large area of crater to the center of the reflector and to a certain extent overcome the dark spot usually present when vertical carbons are used. The initial drawing of the

arc or its reestablishment after running over a line breaker or otherwise interrupting the current, and the feeding of the carbon are automatically controlled by a coil in series with

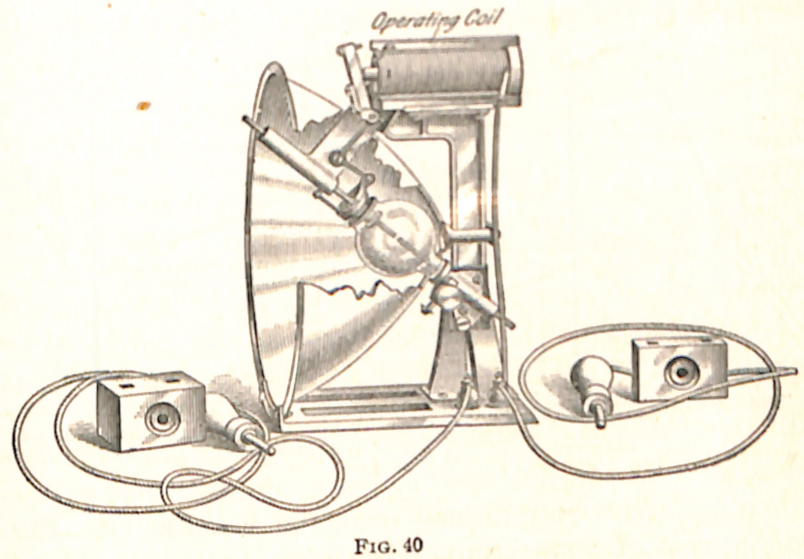


FIG. 40

the arc. The resistance used in series with the arc light is such as to admit a current of $3\frac{1}{2}$ amperes at 550 volts, the drop across the arc then being about 75 volts. Both the

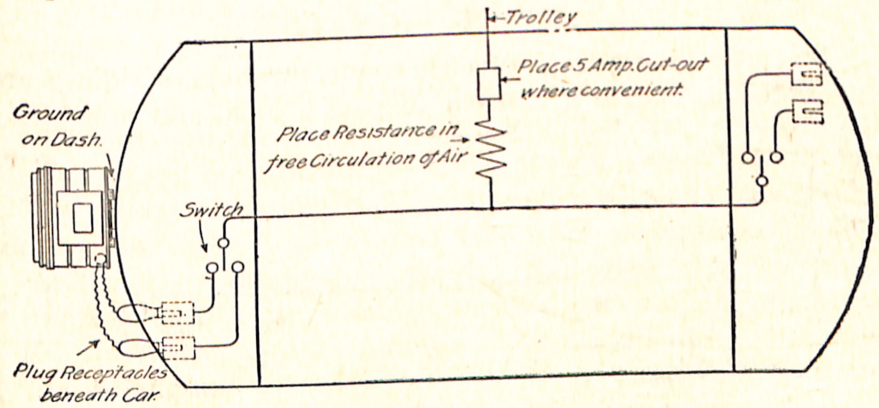


FIG. 41

incandescent attachment, supported on the door, and the arc-lamp circuits have plugs and receptacles of their own, and in order to obviate the necessity of pulling the plug of the lamp

circuit that it is not desired to use, both receptacles are connected to a two-way switch, the position of which determines which circuit shall be supplied with current. When the headlight is changed from one end of the car to the other

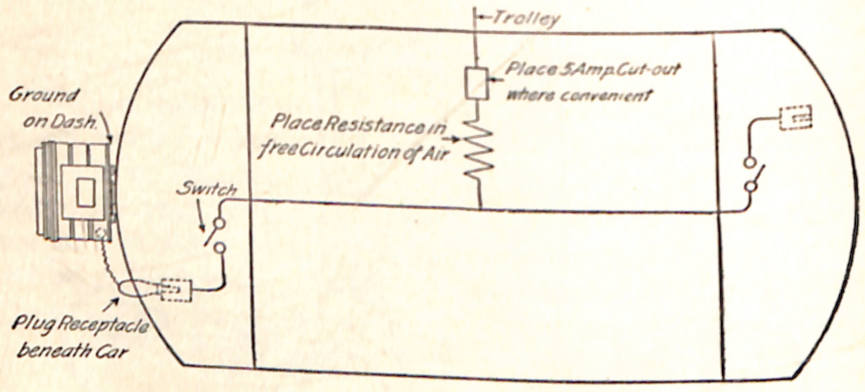


FIG. 42

both plugs must be removed from the receptacles. Fig. 41 is a diagram of connections when both lamps are installed, and Fig. 42, the connections for the arc lamp only, the incandescent attachment being omitted.

TRACK SIGNALS

37. On single-track electric roads, turnouts or sidings are provided to enable a fast car to pass a local and oppositely

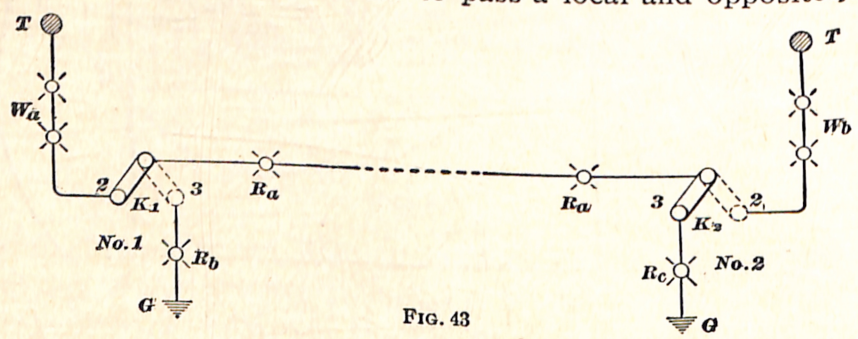


FIG. 43

bound cars to pass each other. The stretches of single track between sidings must be protected by signal systems, so that oppositely bound cars may not meet in collision or a

fast car run into a slow one. In some cases, elaborate automatic signals are installed, but usually the signal system is manual in operation, consisting of a signal-lamp box at each end of the stretch of single track connecting two turnouts. The signal generally takes the form of a red light to block a car, and a white light or no light to show a clear track. Fig. 43 illustrates the connections of a simple signal system.

38. Simple Signal System.—In Fig. 43, K_1 and K_2 are two-way switches, one of which is located at each end of the stretch of single track to be protected. The switch tongues are connected by No. 10 iron wire strung on the line poles and including two 16-candlepower incandescent lamps R_a, R_a provided with red globes. Each switch has a trolley contact 2 and a ground contact 3 including a red lamp (R_b and R_c). Each trolley contact includes two white lamps W_a, W_b. When the two switch tongues are in their full-line positions, white lamps W_a and red lamp R_a burn in the No. 1 signal box, while red lamps R_a and R_c burn in the No. 2 signal box. With the two switch tongues in their dotted-line positions, however, red lamps R_a and R_b burn in the No. 1 box and white lamps W_b and red lamp R_a in the No. 2 box. If both switch tongues rest on contacts of the same polarity, no lamps can burn.

39. Assume that a crew approaching the No. 1 box finds all lights out; under this condition either the system is out of order or both switch tongues are on ground or trolley. The conductor throws the handle to the opposite side, and if the lamps light it shows that they were extinguished by the conductor of another car leaving the block. If the lamps light just before he is able to throw the switch, it means that the conductor on a car entering the other end of the block has thrown his switch and the first car must wait until the second car comes through and clears the block. The conductor before entering the block now throws the switch to the other side to protect himself and throws the switch in the signal box at the other end of the block, when passing out, to clear the block for the next car.

BRAKES

INTRODUCTION

40. The most important part of any car equipment is the **brakes**, and they are closely involved in the financial success of a road. If cars are equipped with modern motive appliances but provided with a poor system of brakes, or if a good system of brakes is grossly neglected, loss due to accidents will be sure to result. Conditions governing the manner of applying brakes effectively vary widely, and the degree to which brakes in good order can be applied depends on the friction between wheel and rail and on that between wheel and shoe. When a brake is applied, the friction between wheel and rail tends to keep the wheel turning, while that between the shoe and wheel tends to stop the latter. The frictional effect tending to stop the wheel or keep it turning depends on the nature of the surfaces in contact and on the force with which the surfaces are pressed together.

The pressure tending to stop the wheel is proportional to the force exerted by the brake shoe; the pressure tending to keep the wheel rolling is proportional to the weight resting on the wheel. The permissible pressure to be applied to a shoe without locking a given wheel will vary with shoes of different material; for example, a shoe pressure that would not lock a wheel braked by an iron shoe might lock it if a wooden shoe were substituted, because the coefficient of friction of wood and iron surfaces is greater than that for iron and iron. In practice, where cast-iron shoes are used to brake cast-iron or cast-steel wheels, long experience has established the rule of making the shoe pressure applied to a wheel 90 per cent. of the weight resting on the rail under the wheel; and foundation brake riggings are designed accordingly. In electric-railway service, however, and

especially in high-speed service employing heavy motors, the pressure applied to the shoe is sometimes made 10 per cent. greater than the weight resting on the rail under the shoe. This increase in the percentage of braking pressure is rendered practicable by the inertia of the heavy rotating armatures, which tend to keep themselves and the geared wheels turning after braking pressure is applied, thereby making the effective weight tending to keep the wheel rolling greater than the actual weight resting on the rail. When all axles do not carry motors, care must be taken to design the foundation rigging so that the extra shoe pressure permitted by armature inertia will be applied only to those wheels that are geared to armatures.

Irrespective of the system of brakes used, the degree to which brakes can be effectively applied and the manner of applying them depend on the condition of the rail. An application that will stop a car satisfactorily on a clean rail may cause the wheels to lock and slide on a slippery one, the slippery condition seeming to affect the rail-wheel friction much more than it does the shoe friction. Braking conditions on a slippery rail are improved by applying sand to one rail, as is usually done, and the improvement is increased 100 per cent. by sanding both rails, as is seldom done, except in steam practice.

On surface trolley cars, hand-brakes are generally used; they can be designed to stop the heaviest cars at high speeds, but in doing so the travel of the brake-lever arms becomes so great that considerable time is required to take it up and effect a stop. On high-speed suburban cars, on elevated cars, and for other heavy traffic, air brakes are used. On single cars or on two-car trains, straight air brakes are used, while on longer trains automatic brakes are depended on. All forms of power-brake equipment, however, are supplemented by hand-brakes, which are retained as a factor of safety in case the power brake should fail or should it be necessary to brake a car cut off from the source of power.

HAND-BRAKES

SINGLE TRUCK

41. Fig. 44 shows a common form of **single-truck brake rigging,** most of the parts of which are designated in the figure. Brake beams B, B are supported on the ends and slide in cast-iron brake-beam castings fixed to the side frames of the truck. In Fig. 45, A is the slide casting; B, the beam; and F, the truck member that supports the casting. Equalizer rods r, r, Fig. 44, connect to equalizer bars E, E and each equalizer rod ends in a jaw J, to which the equalizer bars are rigidly connected, but in which the brake beams move freely, as shown in Fig. 46, where R is the rod; J, the brake jaw; B, the beam; and E, the equalizer bar. In Fig. 44, links H, H are connected to the brake levers L, L and equalizer bars by means of pins. Links I, I connect the brake lever and brake beams. F is a pin around which L and H can move, and F_1 is a pin common to L and B. In the diagram, the brakes are shown off and the shoes have been pulled away from the wheels by the release springs K, K. One end of each spring

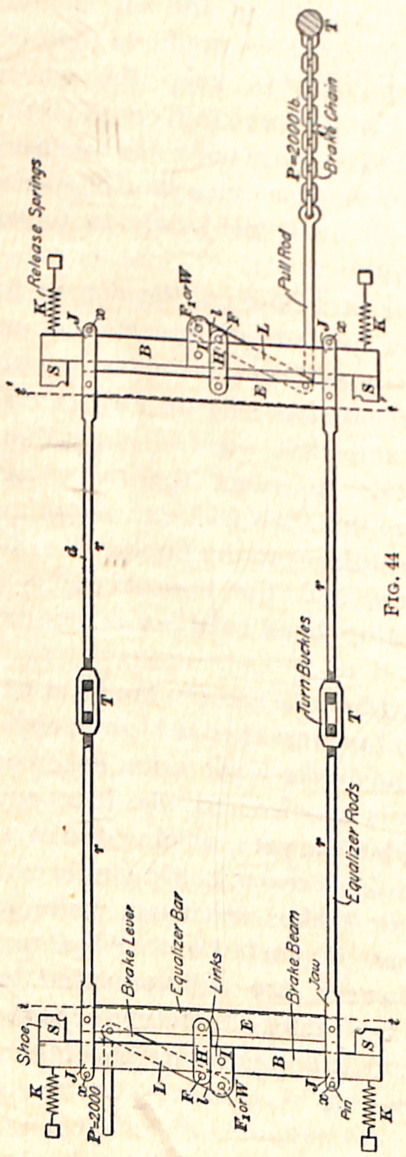


FIG. 44

is fixed to a lug on the car truck and the other end to the brake beam or shoe head. Brake slides wear rapidly and give trouble in winter by getting stopped up with frozen mud; the main objection is that the harder the brakes are set, the harder the brake beams press against the brake slide castings, with the result that the harder the brakes are set, the harder it is to set them. The operation of the brake will be apparent from an examination of Fig. 46. The force exerted on the pull rod P, Fig. 44, draws the brake beams B, B together, and thus presses the shoes S, S against the wheels.

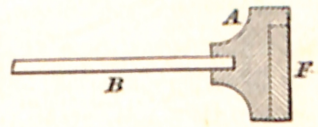


FIG. 45

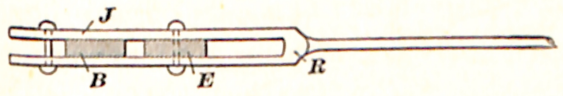


FIG. 46

42. The main objections to existing single-truck riggings are that the release springs do not always effectively keep the brake shoes off the wheels, and the nature of the lever construction is such that the brakes apply harder on the rear end than on the forward end. A glance at the brake rigging of almost any single truck will show that the shoes on one end are an inch or more away from their wheels, while those on the other end cling to their wheels. The brake levers are all released, but the release springs on one end being stronger than on the other pull the weaker springs out and force their shoes to the wheels with pressure depending on the difference in strength of the opposing release springs. Fig. 47 illustrates diagrammatically the leverage of one end of the single-truck rigging of Fig. 44. Lever PFW is 36 inches long and S_2 is the rear brake beam connected to PFW at F, through rod FS_2; S_1 is the front brake beam. Supposing the shoes on beam S_2 to be against their wheels,

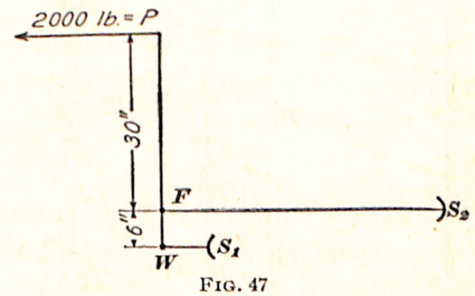


FIG. 47

a pull of 2,000 pounds at P, in the direction of the arrow, will force beam S_1 against its wheels with a pressure of $\frac{39}{6} \times 2{,}000 = 10{,}000$ pounds. Supposing the shoes on beam S_1 to be against their wheels, a pull of 2,000 pounds at P will pull beam S_2 to its wheels with a force of $\frac{36}{6} \times 2{,}000 = 12{,}000$ pounds, a difference of 2,000 pounds, because beam S_1 is applied by a lever having its fulcrum between the applied force and the delivered force, whereas beam S_2 is operated by a lever having the delivered force between the fulcrum and the applied force.

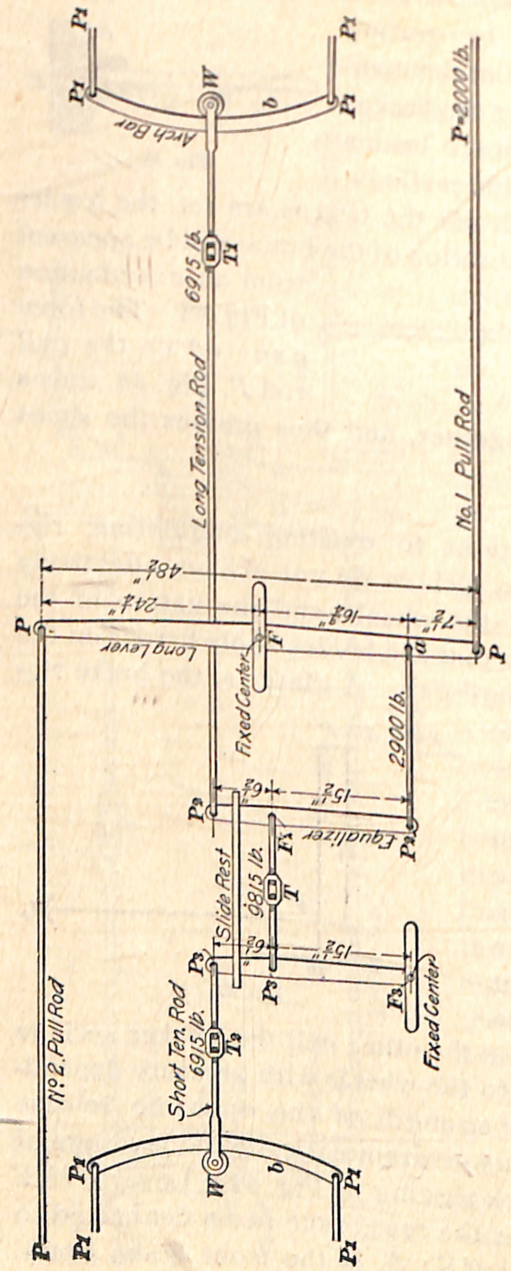


Fig. 48

DOUBLE-TRUCK BRAKES

43. Fig. 48 shows a type of **double-truck rigging** much used. The tendency to apply the rear brakes harder than the forward ones exists on double-truck riggings, and is overcome by the use of an extra equalizing

lever that cannot well be applied to single trucks. In Fig. 48, fulcrum F and fulcrum F_3 of the equalizing lever are fixed to the car body. Levers $P_2 F_2 P_2$ and $P_3 P_3 F_3$ are supported by a strap hanger that permits horizontal sliding motion and are connected by turnbuckle rod $F_2 P_3$. The rigging is indicated in the position of best leverage, the brake being set. Assume a pull of 2,000 pounds to be exerted on lower pull rod P causing the lower end of lever PFP (of which the long arm PF is $24\frac{1}{4}$ inches and the short arm, $16\frac{3}{4}$ inches) to move to the right and thereby exert a pull on rod $a P_2$. The pull on $a P_2$ is $\frac{24\frac{1}{4}}{16\frac{3}{4}} \times 2{,}000 = 2{,}900$ pounds. As rod $a P_2$ connects to lever $P_2 F_2 P_2$, 2,900 pounds is the pull applied to this lever, of which the long arm is $15\frac{1}{2}$ inches and the short arm $6\frac{1}{2}$ inches, the fulcrum being at F_2 and the power being applied to the long arm. Accordingly, the pull on tension rod $P_2 W$ is $\frac{15.5}{6.5} \times 2{,}900 = 6{,}915$ pounds. The pull on turnbuckle $F_2 P_3$ is $6{,}915 + 2{,}900 = 9{,}815$ pounds, which if applied directly to the short tension rod $P_3 W$ leading to the arch bar of the rear truck would apply excessive braking pressure. To avoid such a condition, equalizing lever $P_3 P_3 F_3$ is introduced, the effect of which is to make the pull on short tension rod $P_3 W$, 6,915 pounds, the same as on the long rod $P_2 W$, thereby insuring that the braking pressure on both trucks shall be the same.

44. Rods P_1, P_1 connecting to the ends of the arch bars are the truck pull rods that apply the braking pressure to the truck levers. Fig. 49 shows half the truck rigging on a truck equipped with inside hung brakes. A pull to the left on rod $P P_1$ forces shoes S_1, S_2 against their respective wheels, rod $P_2 P_3$ being subjected to compression.

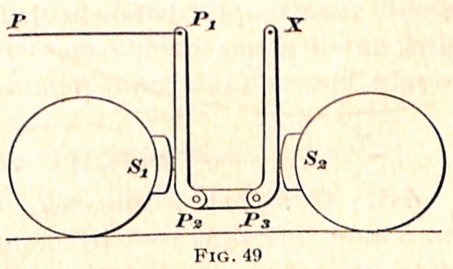


Fig. 49

MAXIMUM-TRACTION BRAKES

45. The body rigging for **maximum-traction trucks** is the same as that for ordinary double trucks, but the truck rigging must be modified to divert the greater part of the braking pressure to the large wheels, the axle of which supports more than two-thirds of the weight of the motor. Fig. 50 illustrates half of the truck rigging used on the Peckham maximum-traction truck. Bent lever A has the truck pull rod connected to its upper end, while its lower end attaches to a push rod that operates the shoe S of the large wheel. Lever A has no stationary fulcrum, but is pivoted at y to lever B, which has a stationary fulcrum at x. The lower end of lever B connects to a push rod that applies the brake shoe s to the small wheel. A pull to the left on the pull rod turns lever A in a counter-clockwise direction on y as a center, thereby applying the large shoe S to the wheel; z then becomes a center around which lever A continues to turn, thereby causing lever B to turn in a clockwise direction on fixed center x, the lower end of B forcing small shoe s against its wheel. The movements of the large and small shoes have necessarily been considered consecutively, but as a matter of fact they take place simultaneously.

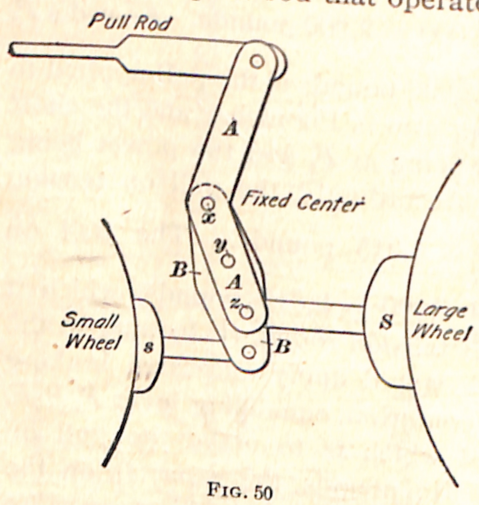


FIG. 50

STRAIGHT AIR BRAKES

46. General Remarks.—By a **straight air brake** is meant one operated by compressed air admitted from a storage reservoir directly to the brake cylinder without dependence on any automatic device. The straight air brake represents one method of securing a quick-acting powerful

brake, effective without manual exertion on the part of the operator, and free in design from excessive leverages. The air used for operating a straight air equipment may be compressed at stations located along the line and stored in a reservoir located on the car, in which case the system is known as the *storage air system;* or the compressed air may be obtained from an air compressor located on the car itself. In the latter case, the compressor may be driven from a car axle, in which case it is called an *axle-driven compressor*, or by an independent electric motor, in which case it is called an *independent-motor-driven compressor*.

47. Principal Parts of Straight Air Equipment. The principal parts of a straight air brake equipment that compresses its own air, are: the *air compressor*, usually driven by an electric motor; the *main reservoir*, or steel tank, into which the compressor stores the air to be used as required; the *automatic governor*, which starts and stops the compressor motor according as the main reservoir pressure is below or above a certain value; the *air gauge*, or *pressure gauge*, usually provided with a red hand, which indicates main-reservoir pressure, and a black hand, which indicates the pressure in the pipe line leading to the brake cylinder or cylinders; the *brake cylinder*, which carries a piston that operates the system of brake levers when communication is established between the reservoir and brake cylinder; the *engineer's valve*, by means of which the motorman lets air into the brake cylinder to apply the brake or discharges brake-cylinder air to atmosphere to release the brake; the *foundation rigging*, consisting of the various levers, rods, and carriers necessary to apply and support the brakes; the *pipe connections*, connecting the engineer's valves, brake cylinder, reservoir, compressor, governor, gauges, and coupling hose when the motor car is to haul a trailer or become part of a train.

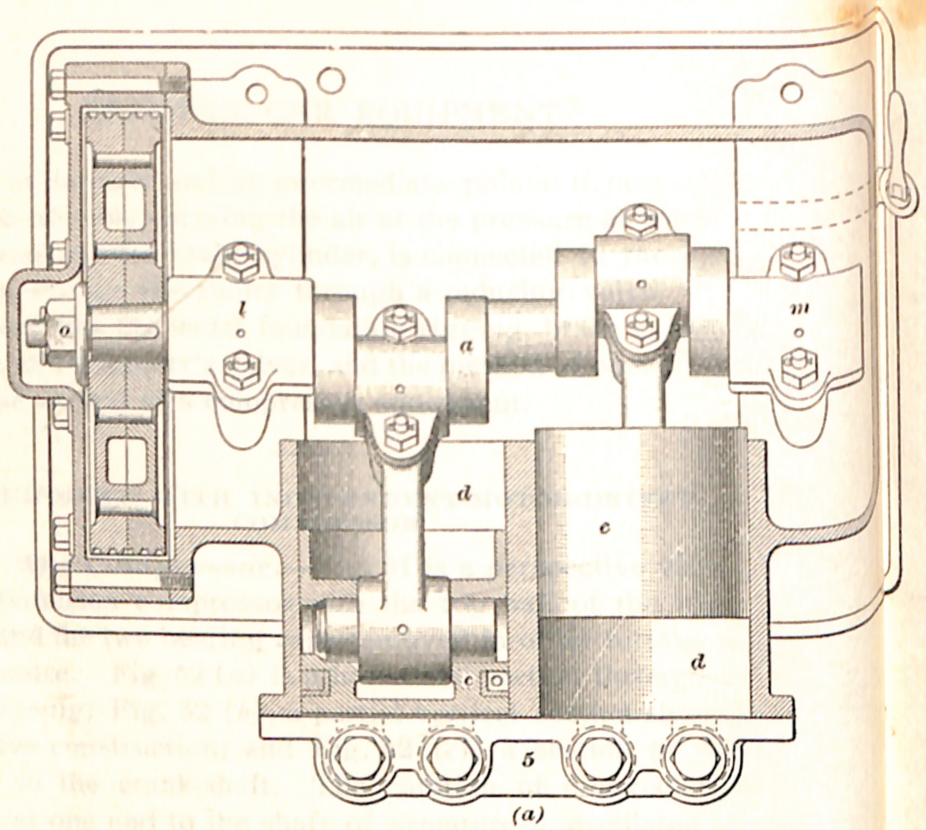
48. On a storage air car equipment, the compressor and all parts connected with it are replaced by reservoirs carrying air stored in them at high pressure at compressor stations

located at termini and at intermediate points, if necessary. A *service reservoir* carrying the air at the pressure at which it is admitted to the brake cylinder, is connected to the high-pressure storage reservoirs through a reducing valve. The equipment has the usual foundation rigging, brake cylinder, gauges, and engineer's valves, and the method of operation is the same as that of a compressor equipment.

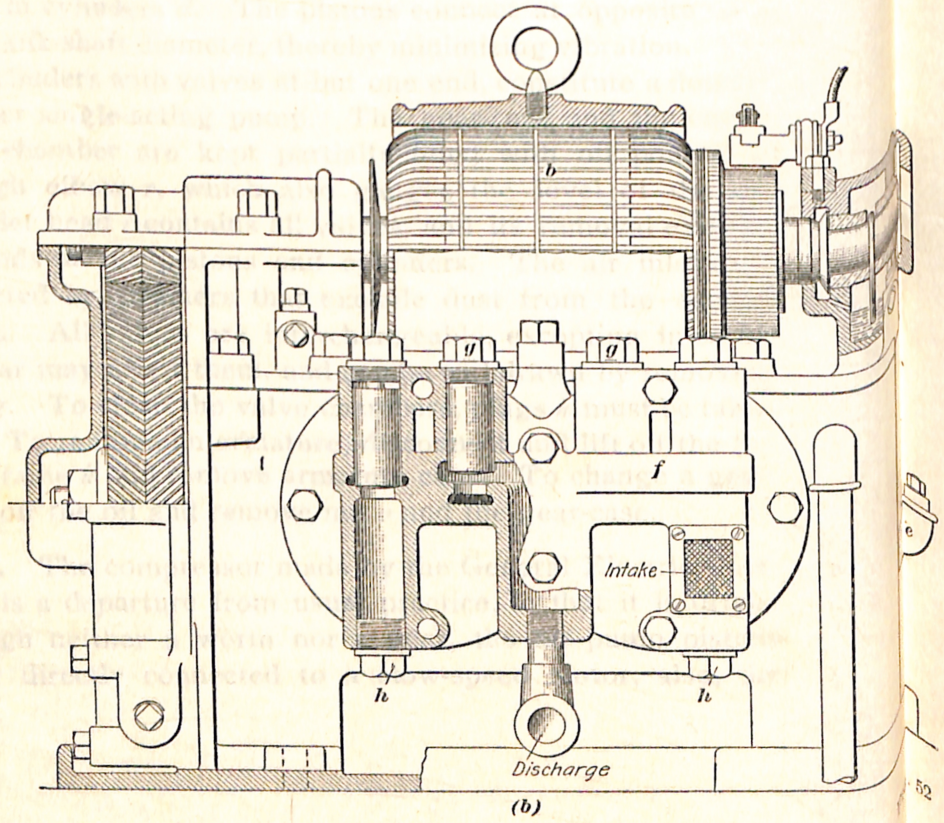
EQUIPMENT WITH INDEPENDENT-MOTOR-DRIVEN COMPRESSOR

49. The Compressor.—Fig. 51 is a perspective view of the Christensen compressor with the top half of the motor frame and the two bearing caps removed in order to take out an armature. Fig. 52 (*a*) is a horizontal section through the pump casing; Fig. 52 (*b*), a partial vertical section showing the valve construction; and Fig. 52 (*c*), a section at right angles to the crank-shaft. The rotation of crank-shaft *a*, geared at one end to the shaft of armature *b*, oscillates pistons *c* in cylinders *d*. The pistons connect at opposite ends of a crank-shaft diameter, thereby minimizing vibration. The two cylinders with valves at but one end, constitute a double-cylinder single-acting pump. The gear-case and the crank-shaft chamber are kept partially filled with oil poured in through elbow *e*, which also gauges the level of the oil. Cylinder head *f* contains all valves, and its removal exposes the ends of the pistons and cylinders. The air inlets are protected by strainers that exclude dust from the suction valves. All valves are interchangeable, excepting in so far as wear may affect them, and can be withdrawn by removing caps *g*. To clean the valve chambers, plugs *h* must be taken out. To remove an armature, disconnect and lift off the top field frame *k* and remove armature caps. To change a gear draw off the oil and remove nut *o* and the gear-case.

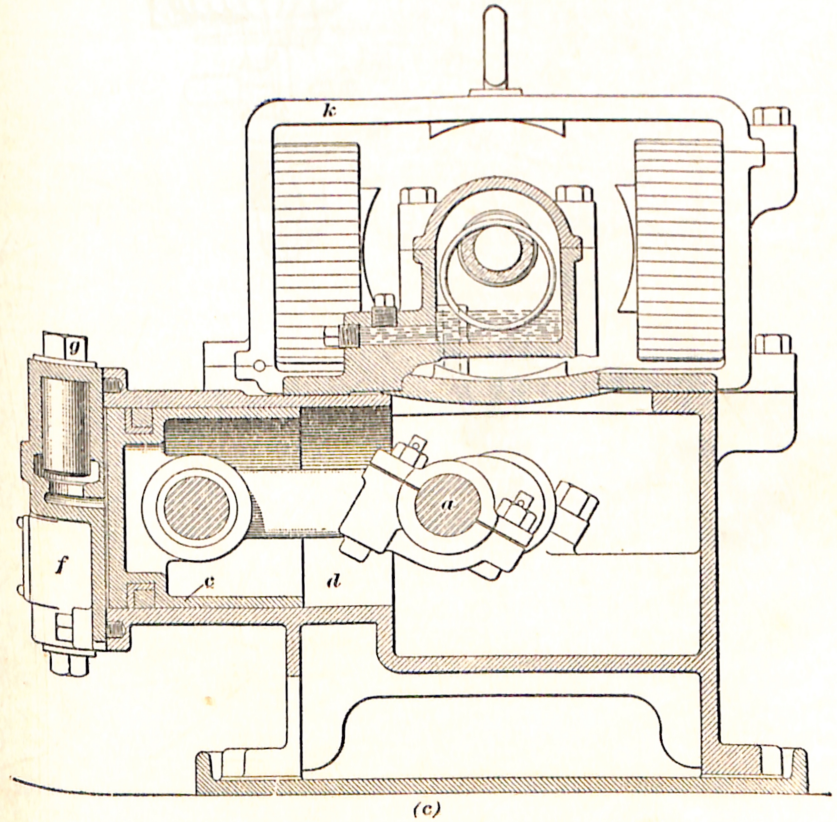
50. The compressor made by the General Electric Company is a departure from usual practice, in that it is driven through neither a worm nor a gear, the air pump pistons being directly connected to a slow-speed motor, also, the



(a)



(b)



(c)

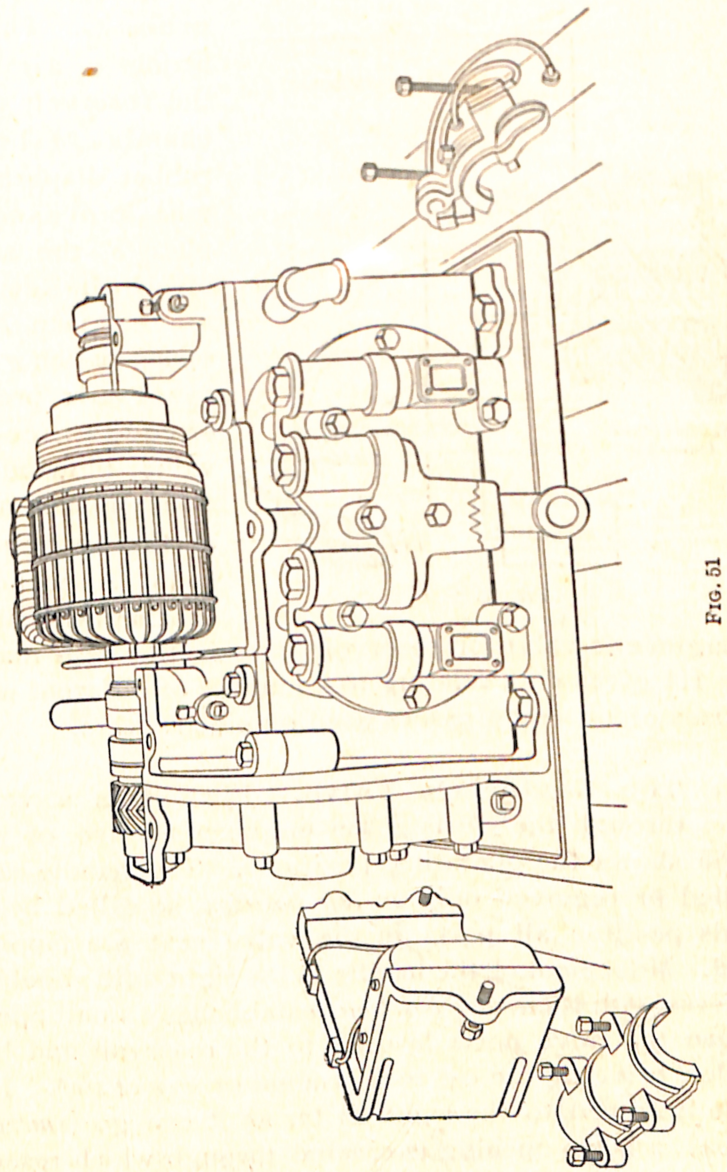


FIG. 51

pump action is compound instead of duplex. Fig. 53 is a sketch of connections showing a section through the governor *G*. Through fitting *a*, air from the reservoir enters chamber *b* behind rubber diaphragm *c*, which presses on plate *d*, the stem *e* of which actuates mechanism *f* and opens switch *g* when reservoir pressure exceeds a certain value; blow-out coil *h* suppresses arcing at the switch contacts. A second pipe (not shown) runs to the engineer's valve or reservoir line, as the case may be. Table III gives data relating to a number of different makes and sizes of air compressors used on electric cars.

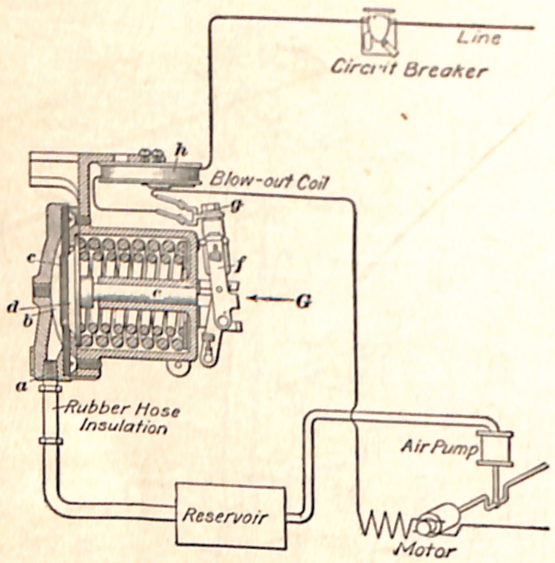


FIG. 53

51. The Engineer's Valve.—Fig. 54 is a vertical section through the Christensen engineer's valve, of which Fig. 55 shows the operating positions. The handle can be installed or removed only on *lap position*, so called because on this position all ports in the valve seat are lapped or closed. Movement of the handle to the right until shoulder *m* interferes with it (*service position*) establishes a small opening between the valve ports leading to the reservoir and brake cylinder, bringing the car to a gradual or *service stop*. If the handle is forced to the right as far as it can go (*emergency position*), a large opening is created through which reservoir air rushes to the brake cylinder, bringing the car to an *emergency stop*. On the first position to the left of lap, a small opening is created between the brake cylinder and atmosphere, allowing the brake to release gradually; this position

TABLE III

CAPACITY OF MOTOR-DRIVEN AIR COMPRESSORS

Name of Compressor	Cylinder Dimensions Inches	Revolutions per Minute	Free Air per Minute Cubic Feet	Horse-power at 90 Pounds	Size of Fuse Amperes	Diameter of Suction Pipe Inch	Diameter of Discharge Pipe Inch	Length Inches	Width Inches	Height Inches	Net Weight Pounds
General Electric C. P. 14	$5\frac{7}{16} \times 2\frac{1}{2}$	300	20	5.00				28	$22\frac{3}{4}$	$15\frac{1}{2}$	800
General Electric C. P. 17	$4\frac{3}{4} \times 2$	300	12	3.25				$27\frac{1}{2}$	$19\frac{3}{8}$	13	600
Christenscn A-5	$4\frac{1}{2} \times 2$	200	7.5	1.50	5	$\frac{1}{2}$	$\frac{1}{2}$	$19\frac{3}{8}$	16	$14\frac{1}{4}$	265
Christensen AA-1	$5 \times 2\frac{1}{2}$	195	11	2.20	7	$\frac{3}{4}$	$\frac{3}{4}$	$21\frac{13}{16}$	$18\frac{13}{16}$	$16\frac{3}{4}$	406
Christensen B-2	$6\frac{1}{2} \times 3$	175	20	4.00	10	$\frac{3}{4}$	$\frac{3}{4}$	$28\frac{15}{16}$	$20\frac{3}{8}$	$20\frac{13}{16}$	725
Christensen C-3	$7\frac{1}{2} \times 4$	175	35	7.00	15	1	1	$32\frac{1}{4}$	$24\frac{7}{16}$	23	950
Christensen D-4	$8\frac{1}{2} \times 4$	180	50	9.50	20	1	1	$35\frac{7}{16}$	25	$24\frac{3}{8}$	1,118
Westinghouse D-1 B . .	$5 \times 2\frac{11}{64}$	265	13.1	3.18	5	1	$\frac{3}{4}$	26	$23\frac{1}{4}$	16	633
Westinghouse D-2 B . .	$5\frac{1}{2} \times 4\frac{1}{4}$	243	23.4	5.40	10	1	$\frac{3}{4}$	$30\frac{5}{8}$	$27\frac{1}{8}$	$19\frac{3}{4}$	918
Westinghouse D-3 B . .	7×5	162	36	9.20	15	1	$\frac{3}{4}$	$33\frac{3}{4}$	$28\frac{1}{2}$	$22\frac{1}{4}$	1,185

is used for gradual releasing and for running and is therefore called the *slow-release* and *running position*. If instead of moving the valve handle to this position after an application it is moved to the extreme left to *quick-release position*, the

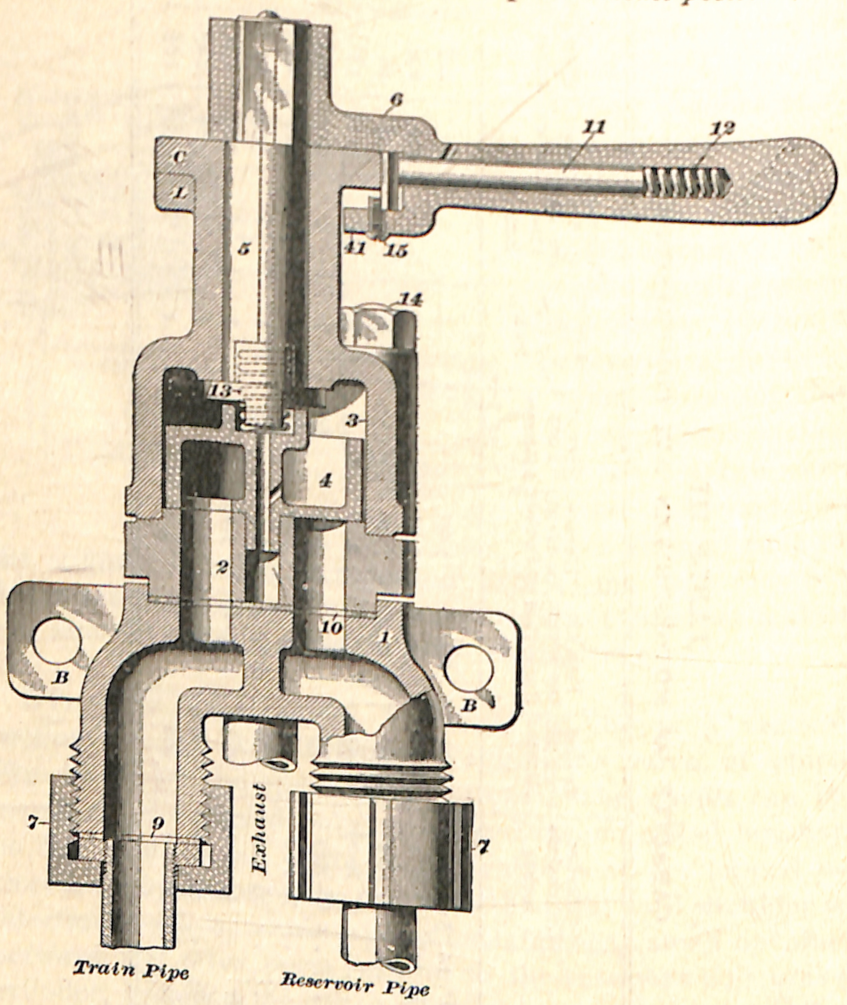


FIG. 54

size of the opening between the brake cylinder and atmospheric ports is such that the brake-cylinder air rushes out, allowing the release springs to release the brakes suddenly. On cars under headway, the valve is kept on slow-release, because the opening here existing between the brake cylinders

and atmosphere precludes the possibility of leakage across the face of the valve admitting air to the brake cylinder to set the brake unknown to the motorman. Quick-release is used for fully releasing the brake preparatory to starting after having made a stop. Slow-release is used for letting some of the air out of the brake cylinder when it is found

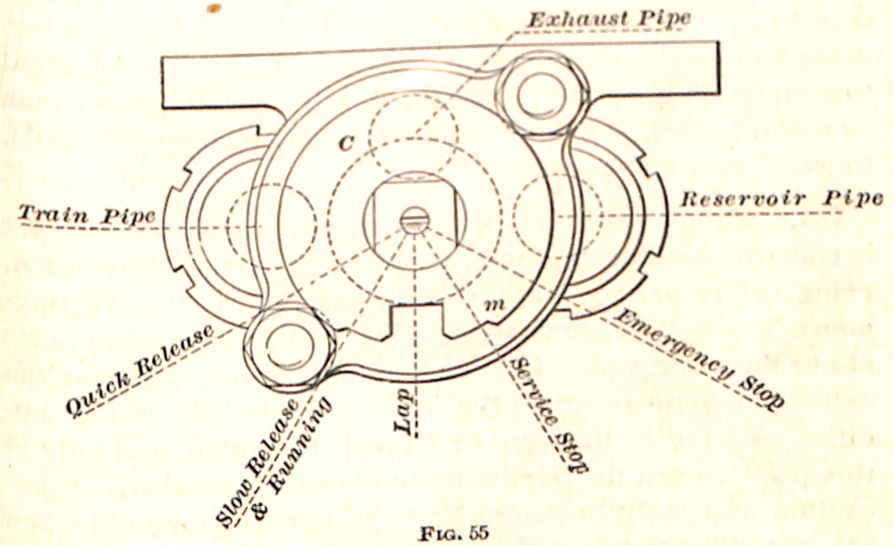


FIG. 55

that the car is going to stop too soon. The emergency position is used only in time of danger, and an emergency application should be accompanied by a liberal application of sand to the rail. An emergency application does not set the brake any harder than a prolonged service application, but sets it more quickly.

52. Each application of the brake reduces the pressure available for the next stop, but if the automatic governor is in order, the pressure cannot fall below a certain amount, for which the governor is adjusted. When the governor is out of order, however, it must be cut out and the starting and stopping of the compressor controlled by hand. Under this condition, the motorman must watch the pressure gauge and pull the switch when the gauge indicates maximum allowable reservoir pressure and close it when leakage or usage reduces the pressure to nearly the lower allowable limit.

The general practice is to allow a margin of 10 pounds, the maximum limit being 60 or 65 pounds and the minimum 50 or 55; there is, however, a tendency toward employing higher pressures—80 to 90 pounds. To reduce reservoir pressure from 60 to 50 pounds requires at least two emergency applications; the number of service applications required depends on the efficiency with which the applications are made and on the local track conditions. Less air is required to stop on an up grade than on a level; less on a level than on a down grade; and less on slippery rails than on good rails, to avoid locking the wheels.

53. Valves made by different companies vary somewhat in construction details, some, as in the case of the Christensen, being rotary valves, while others, like that of the Westinghouse Traction Brake Company, being slide valves; all operate to the same end. The off, or lap, position is always the neutral position in which the braking air is held in the condition existing at the time of lapping the valve, and only in this position can the handle be removed or installed—a precaution necessary to insure that the brakes may hold when the motorman removes the handle to change ends on a grade. Air at high pressure is hard to hold, and too much reliance must not be placed on lap position to hold air in the brake cylinder for a prolonged period. A car braked with air should not be left unattended unless the hand-brake has been set. If the handle is left on service position, all air must leak out of both the brake cylinder and reservoir before the brakes will release. If the governor and compressor are cut in and are in good condition, it cannot do this, but the pressure will be maintained at great loss of energy not to mention wear and tear on the compressor.

54. The Pressure Gauge.—A pressure gauge indicates the air pressure in the device to which it connects. Where two or more air-braked cars are to be operated together, a gauge having two hands, and called a *duplex gauge*, is used; one hand indicates main-reservoir pressure and the other the pressure in the *train line* or pipe connecting the brake

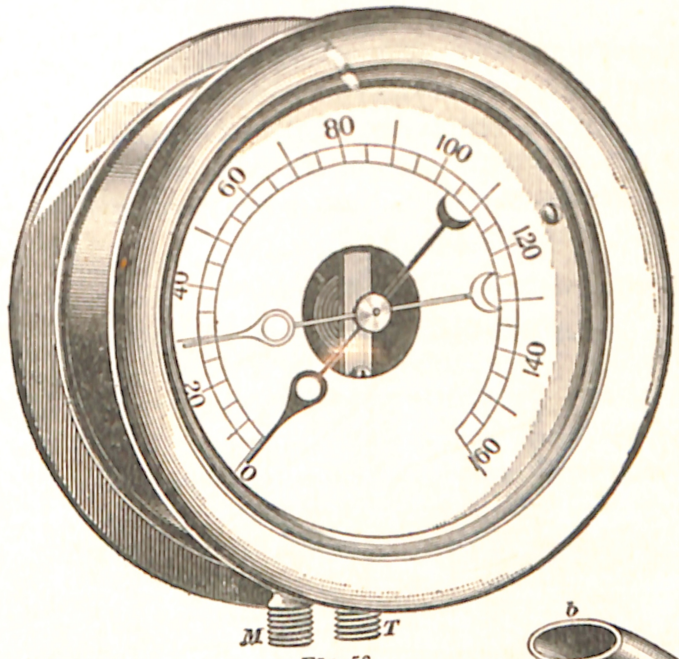
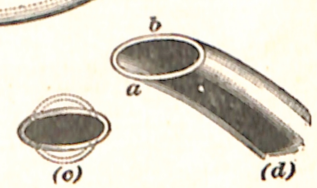


FIG. 56



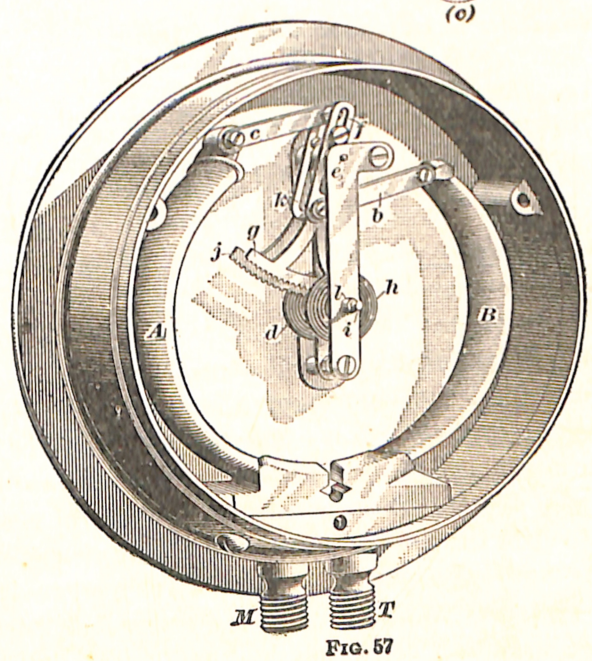


FIG. 57

cylinders together. Ordinarily, single-hand gauges are used on single cars, only main-reservoir pressure being indicated, but a duplex gauge represents the best practice in that it shows at a glance whether the brake cylinder contains air or not, and minimizes the probabilities of starting or running with the brake partially set.

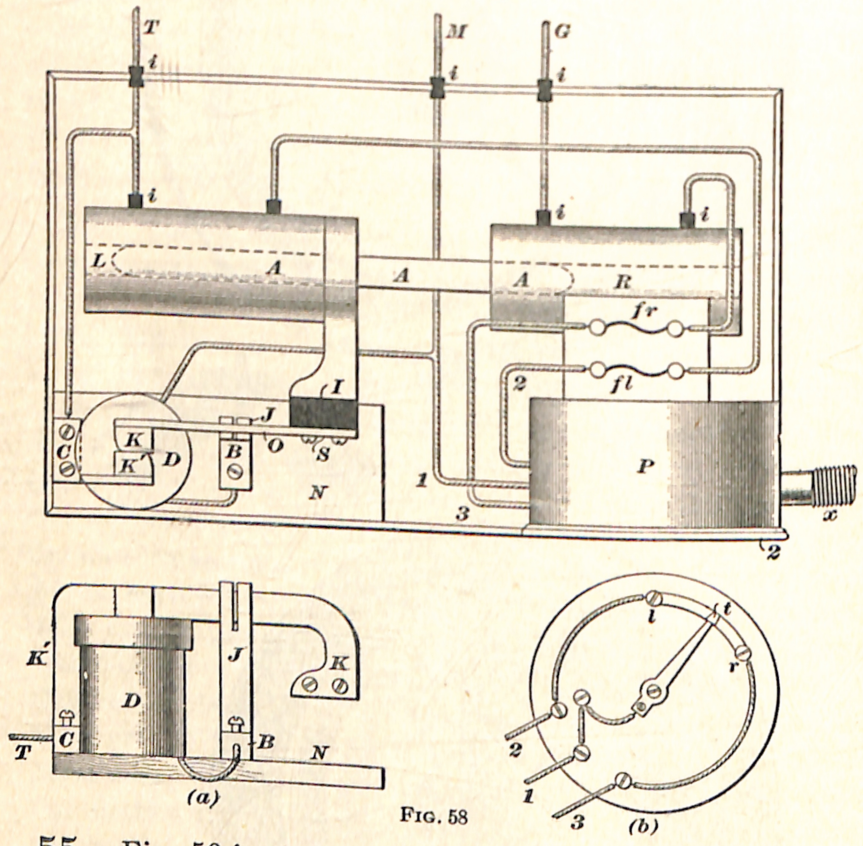


FIG. 58

55. Fig. 56 is a general view of a duplex air gauge, of which Fig. 57 shows the internal mechanism. The thin metal lobes A, B have the cross-section indicated in Fig. 57 (d), but internal pressure due to the compressed air tends to change them to the dotted cross-section of Fig. 57 (c), thereby giving the ends of the lobes lateral movement. Through racks j, g pivoted at e, the end motions of lobes A, B, respectively, are transmitted to pinions d, h on spindles i, l concentric with the pinions. These spindles carry the gauge hands, and since

lobe A fastens to the rack above the fulcrum and lobe B below the fulcrum, both hands move around the dial in the same direction. Connection M to the main reservoir admits air to the lobe that operates the red hand, while connection T to the train line admits train-line air to operate the black hand.

56. Automatic Governor.—Fig. 58 is a top view of the Christensen automatic governor, generally called the pump governor. L and R are electromagnets in which an iron armature A carrying an extension I is free to slide. K and K' are contact fingers, K' being stationary and K being carried by, but insulated from, extension I. D is a magnetic blow-out coil through which the current passes and which suppresses arcing when fingers K, K' are pulled apart. P is the regulator constructed on the same principle as a single-hand air gauge; the hand, however, instead of indicating pressure carries on its end a carbon knob t, which, according to the condition of main-reservoir pressure, touches contacts l or r. Connection x leads to the main reservoir. Fuses f_r, f_l protect the governor magnets. Connections T, M, and G passing through insulating bushings i connect, respectively, to trolley, the pump motor, and the ground. The connection to the regulator hand is made very flexible to avoid interfering with the movement of the hand.

57. Fig. 59 is a sketch of the connections of the governor of which the operation is as follows: The regulator hand t is so adjusted that at minimum allowable main-reservoir pressure, or less, it rests against contact post l leading to magnet L. Suppose that the reservoir is empty and that it is necessary to get up pressure: On closing the pump switch K, current comes in at T to junction X; if magnet L had been the last one to operate, armature $A\,A$ would be at the left end of its travel and fingers K, K', Fig. 58, would touch, so that current could take path X–C–B–D–Y–M–M'–W–G, Fig. 59, through the pump motor and start it; the current through magnet L is negligible because it is practically short-circuited by the path just traced. In this particular case, then, when armature $A\,A$, Fig. 58, is already in the proper position

coil L does nothing. Suppose, however, that at the time of closing the pump switch, armature $A\,A$ happens to be to the right so that fingers K, K' cannot touch; in this case no current can get across the open circuit between C–B, and the pump motor cannot start at once; but current takes path X–L–f_l–l–t–Y–M–M'–W–G, Fig. 59, thereby exciting magnet L, causing it to jerk all parts to the left, thereby closing the motor circuit and simultaneously short-circuiting the magnet circuit, as already explained. As the gradually increasing pressure in the main reservoir and hence in the regulator lobe straightens out the lobe, knob t moves from contact post l toward contact post r. The instant it touches

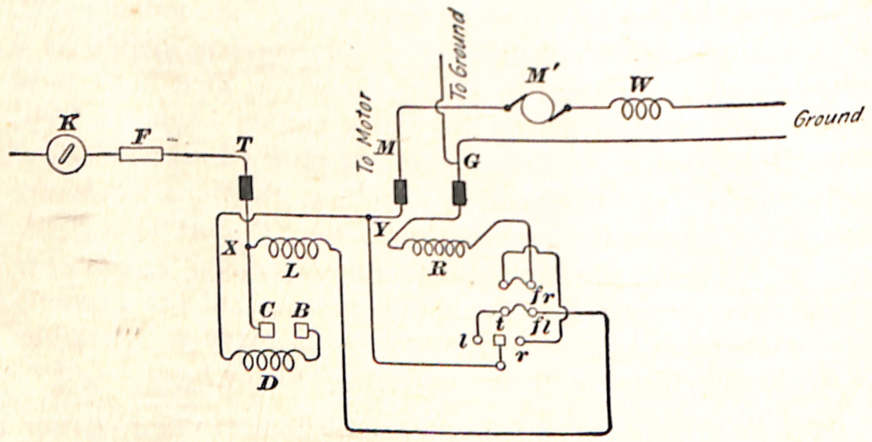


FIG. 59

post r, trolley current takes path T–X–C–B–D–Y–t–r–f_r–R–G, thereby exciting magnet R, which pulls armature $A\,A$, Fig. 58, to the right, opening the motor circuit and simultaneously stopping all current flow through itself. Armature $A\,A$ will remain at the right-hand end of its travel until usage or leakage reduces main-reservoir pressure to its lower allowable limit, when contact between regulator knob t and contact post l will again cut in the compressor.

Connecting posts r and l can be slid back and forth in the circular slot indicated in Fig. 58. By adjusting these posts in the slot, the governor can be made to cut in the compressor at one pressure and out at another.

58. The Brake Cylinder.—Fig. 60 is a section through a standard brake cylinder made by the National Electric Company (Christensen Engineering Company). In Fig. 60, *1* is the cylinder body; *2*, the front head; *3*, the back head; *4*, the piston; *6*, *7*, the front and back forks through which pass bolts *15* and *16*, around which turn the cylinder levers of the foundation brake rigging; *8* is the release spring; *11*, the piston packing bolts; *12*, the head-bolts; *13*, the hollow piston stem; *P*, the push rod. At *11* is a threaded hole for the piping to the engineer's valve.

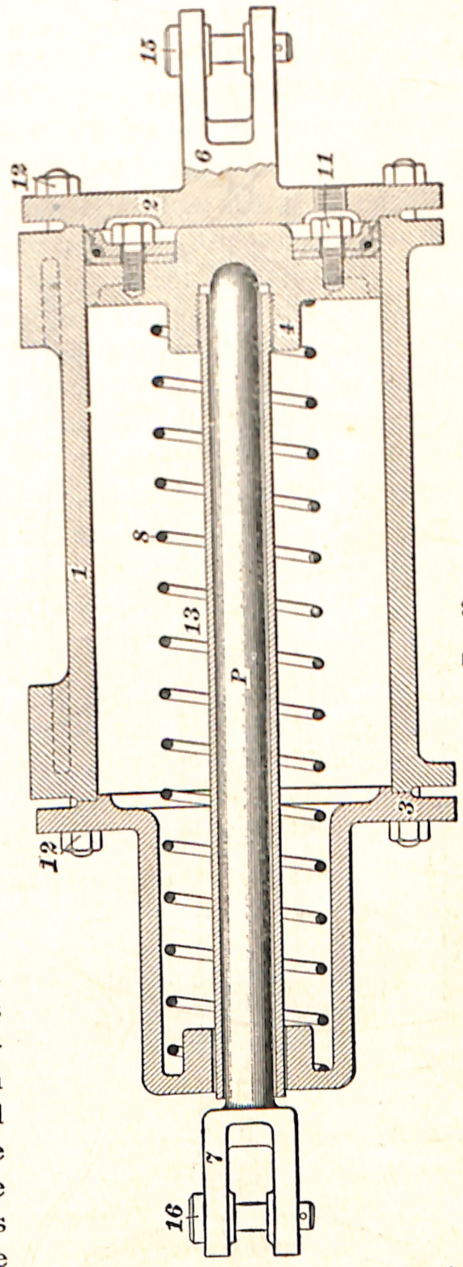


FIG. 60

The operation of the cylinder parts is as follows: Fork *6* is stationary; fork *7* moves back and forth with rod *P*, which operates the cylinder levers. Air admitted through hole *11* forces piston *4* to the left, carrying with it rod *P*, which moves the lever connected to pin *16* and sets the brakes. In moving to the left piston, *4* compresses spring *8*, so that when the brake valve is moved to release position exhausting brake-cylinder air to atmosphere, spring *8* returns piston *4* and

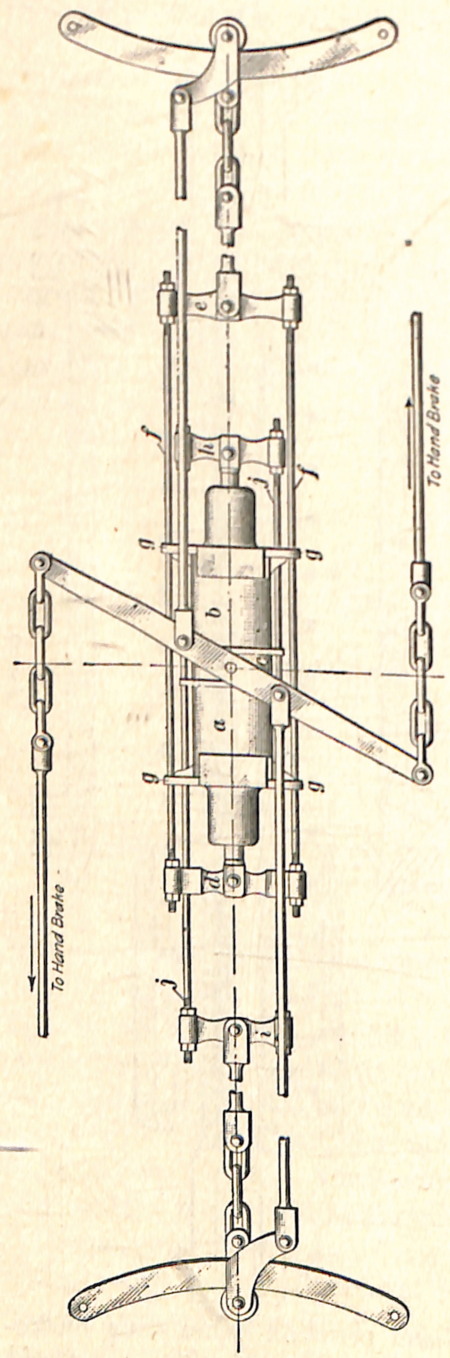


FIG. 61

hollow stem *13* to normal position. Since fork 7 and push rod *P* are independent of stem *13*, the push rod must be returned to normal position by the release springs on the brake rigging. The object of having *P* and *13* independent of each other is that when the hand-brake is used and push rod *P* must be pulled out, it will not be necessary to pull out *4* and *13* against the tension of spring *8*. The brake-piston travel should be kept within the limit prescribed by the manufacturing company, because beyond this limit the side pressure of the push rod *P* will be sufficient to split out the end of the hollow stem *13*.

59. Fig. 61 shows a brake cylinder manufactured by the Philadelphia Air Brake Company. As it really consists of two brake cylinders, each with its own piston rigging, it is called a **duplex** cylinder. In Fig. 61, *a* and *b* are the two cylinders accurately alined and bolted together at *c*, by flange bolts (not shown). Crosshead *d*, operated by

the piston of cylinder *a*, is connected to crosshead *e* by rods *f* that pass through guides *g*; and crosshead *h* operated by the piston of cylinder *b*, is connected to crosshead *i* by rods *j*, which also pass through guides *g*. Crosshead *e* is connected, by means of rods, to the arch bar that distributes the pull applied to the truck on one end and crosshead *i* is connected to the arch bar on the other end. When the air pressure is admitted to the cylinder space between the two pistons, they move apart, the one in cylinder *a* applying the brakes on the right-hand end and the piston in *b* applying them on the left-hand end. The breaking of a rod or lever connected with the rigging of one piston does not interfere with the braking power of the other, because the two riggings are entirely independent. The duplex air riggings, together with the independent hand-brake rigging shown, constitute three independent means of braking in an emergency. The duplex arrangement of cylinders simplifies the foundation rigging and equalizes the brake pulls applied to the two trucks without the use of special levers for that purpose.

60. The Reservoir.—The reservoir, Fig. 62, is a steel tank generally supported under the car by iron hangers bolted to the sills, but sometimes placed inside the car under the seats or even on the car roof. In cases where space is limited, two smaller reservoirs can be used instead of one

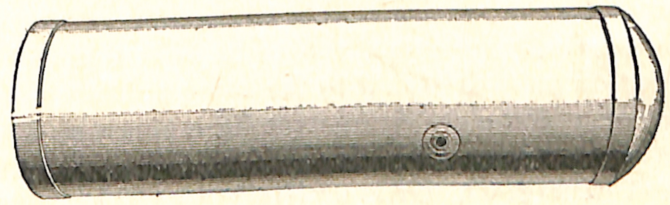
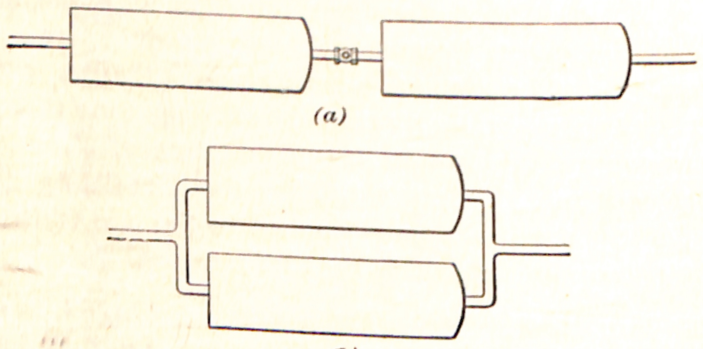


FIG. 62

large one. In such a case the two reservoirs should be piped in series, as indicated in Fig. 63 (*a*), and not in parallel, as in Fig. 63 (*b*). The first connection has the advantage that most condensation takes place in the first reservoir, leaving comparatively dry air to be used from the second one. The greater the capacity of the main reservoir, the higher is the

pressure with which it will equalize with a brake cylinder of given capacity in an emergency application and, hence, the quicker will be the stop. Also, the larger the reservoir, the longer will be the periods of rest and consequent cooling afforded the compressor motor, because once charged to maximum pressure, the greater are the number of applications that can be made without reducing the pressure sufficiently to cut in the compressor. For these two reasons, then, the main reservoir should be as large as practicable. In practice, main reservoirs and brake cylinders are limited to standard sizes adopted by the manufacturers.



(a)

(b)

FIG. 63

61. Layout of Devices.—Figs. 64 and 65 show a layout of the Christensen straight air-brake equipment and give an idea of the location and interconnection of devices. If the two drawings are conceived to be held together so that points *a*, *b* on one register with the same points on the other, the result is a complete equipment for a single-end car; and if an extension similar to Fig. 65 be added also to the right-hand end of Fig. 64, the complete layout for a double-end car is the result. In these figures are indicated devices not heretofore considered—pipe and lever connections, coupling and insulation hose, hand-brake, and whistle.

62. The **air-brake lever system** is shown in Fig. 64, and consists of front and back cylinder levers *A*, *B* connected by rod *C*. Front and back brake rods *D*, *E* connect at one end to their respective cylinder levers *A*, *B* and at the other

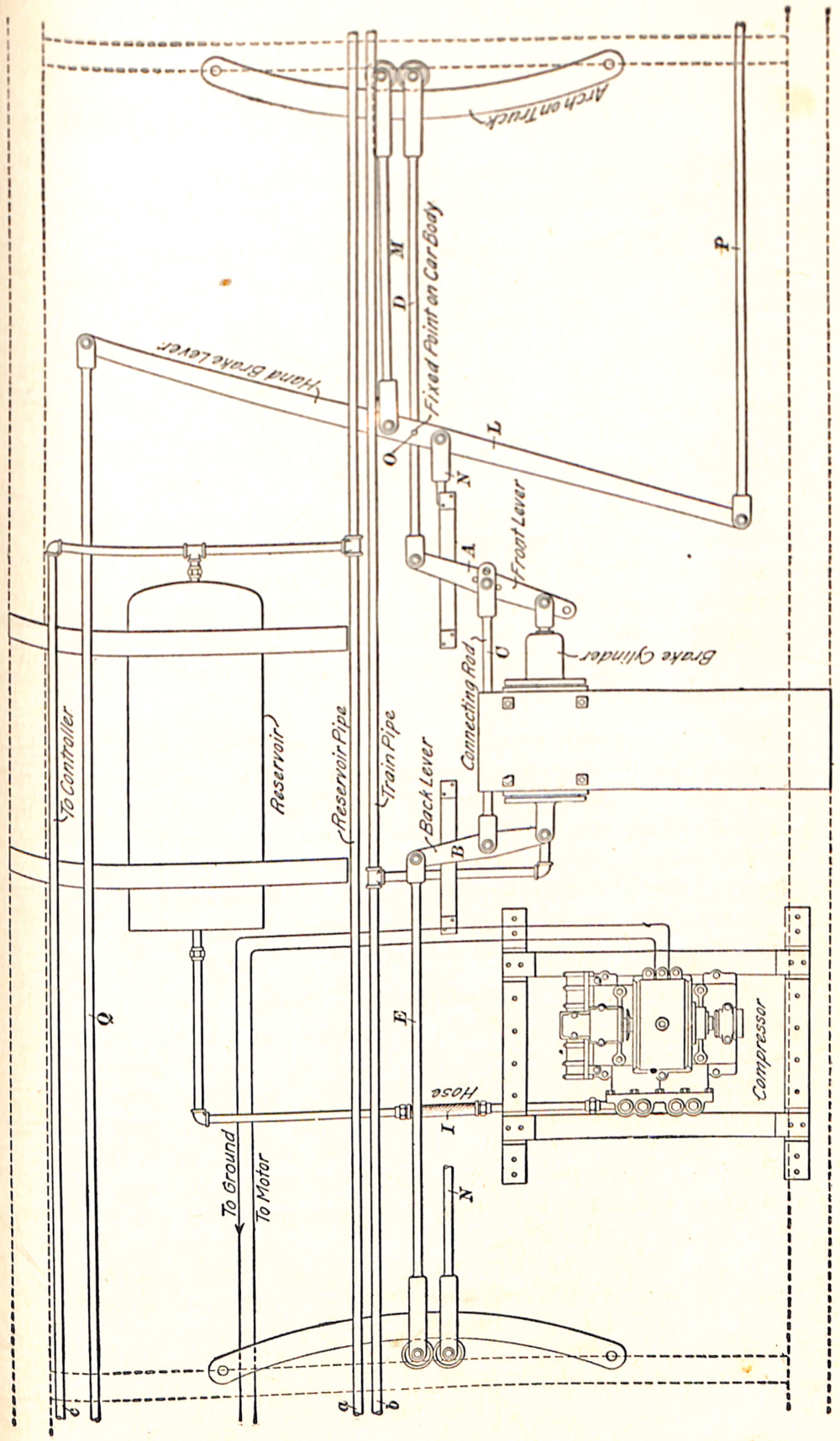


FIG. 64

end to the truck arch bars to which connect the pull rods from the individual truck brake riggings (not shown).

63. The **hand-brake lever system** is independent of that of the air brake, but in all cases its stresses are in the same direction. Hand-brake lever *L* is attached to the car body at *O*; pull rods *P* and *Q* fasten to the hand-brake staff through the brake chains. Winding up either chain, by turning the hand-brake wheel, causes lever *L* to turn around *O*, thereby pulling on brake rods *M* and *N*, which connect to the arch bars independently of air-brake rods *D*, *E*.

64. The **piping system** consists of a reservoir pipe *a* and train pipe *b* extending the full length of the car in the case of double-end control, but extending only from the engineer's valve to the brake cylinder and main reservoir in single-end control. The compressor is piped to the reservoir, the other end of which is joined to the reservoir pipe and pump governor (see pipe *c*, Figs. 64 and 65).

65. The **insulation hose** *I*, *I* are used to insulate the governor and compressor from the grounded devices to which they connect. When the frame of a device operating on a ground-return system is not grounded, the tendency of any current-carrying part to ground to the frame is greatly reduced. Two connections with the frame will be necessary to interfere with the operation of the affected device. In many cases an insulating coupling is used instead of the piece of hose.

66. Operation of Equipment.—Before taking a car out, the governor cock must be turned on and the pump switch closed. The governor will then cut in and start the compressor, which will store air in the reservoir until its pressure reaches standard value. On running a car into the house for the night, the pump switch should be opened, otherwise, if the pipe system has leaks, they will keep the governor cutting in and out and the compressor in intermittent operation all night.

In Fig. 65 only one snap switch is shown in the pump circuit; on double-end cars, two pump switches, one on each

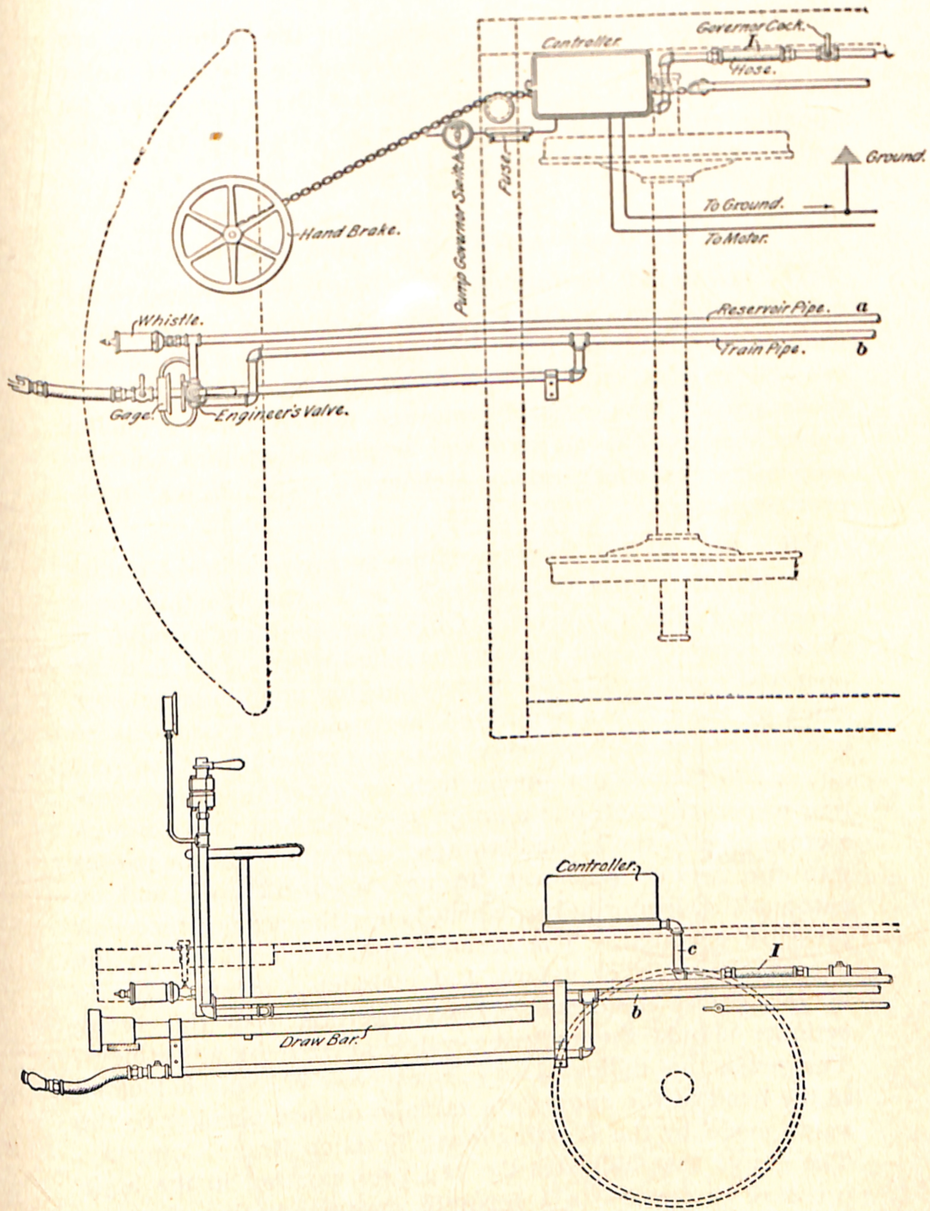


FIG. 65

end of the car and within easy reach of the motorman, are preferable, so that should the governor get out of order the motorman can conveniently control the air pressure by opening and closing the pump switch irrespective of the end on which he may be operating.

STORAGE AIR-BRAKE EQUIPMENT

67. General Remarks.—The engineer's valve, brake cylinder, reservoir, and lever system, and most of the piping used on an independent-motor straight air-brake equipment, can also be used on a storage air equipment. In addition to these parts, there must be storage reservoirs, a reducing valve between the storage and service reservoirs, various stop-cocks and check-valves, a charging coupling, and high-pressure gauge.

68. Fig. 66 is a diagram of the storage air-brake equipment installed on a double-truck car by the Westinghouse Traction Brake Company. Only one engineer's valve is shown connected, but two are installed where a car is to be operated from both ends. The charging couplings on both sides of the car are connected by a pipe that connects to one end of the high-pressure storage reservoirs. Charging air, at 325 pounds per square inch, on entering either coupling passes through one storage reservoir and then through a cross-pipe to the second storage reservoir. The air passes into the service reservoir through a cut-off cock and an automatic reducing valve, which keeps the service-reservoir pressure constant. The service reservoir connects to the engineer's valve, or valves, and includes a safety valve to insure against abnormal pressure getting into the brake cylinder should the reducing valve get out of adjustment. The gauge that indicates service-reservoir pressure is located in the head of the engineer's valve, a feature peculiar to the valve made by the Westinghouse Traction Brake Company. The gauge that indicates the pressure existing in the high-pressure reservoirs is a separate instrument that connects directly to one of them.

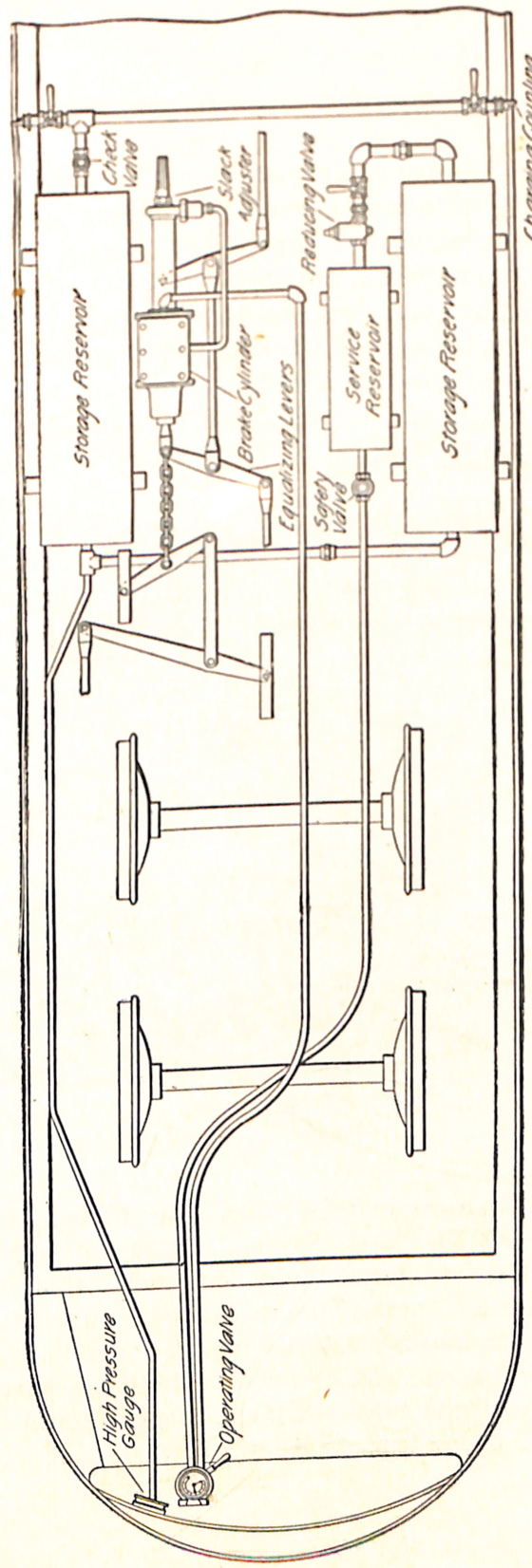


FIG. 66

69. The Reducing Valve. — The reducing valve employed for maintaining constant pressure in the service reservoir is the well-known Westinghouse **slide-valve feed-valve** used for maintaining constant train-line pressure on automatic air-brake equipments. In the storage air equipment, the valve body is adapted for pipe connections from the storage and service reservoirs instead of a fitted

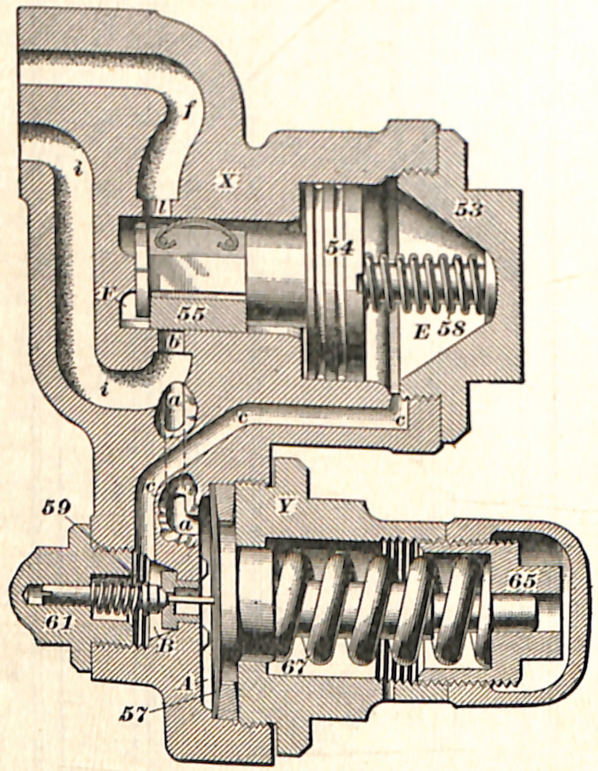


FIG. 67

connection to an engineer's valve. Fig. 67 is a conventional diagram in which the upper and lower valve parts, which are in planes at right angles to each other, have been revolved into the same plane in order to show the ports and passages more clearly. When used as a reducing valve, as on the storage air equipment, the high-pressure reservoir connects to a pipe fitting leading to port *f* and the service reservoir to a pipe leading to port *i*.

The operation of the valve is as follows: Storage-reservoir pressure is in continuous communication with chamber *F* through port *f*; chamber *E*, separated from chamber *F* by supply-valve piston *54*, is connected to passage *i* and thus with the service reservoir through passage *c c*, port *a* (controlled by regulating valve *59*), and chamber *A* over metal diaphragm *57*. Regulating valve *59* is normally held open by diaphragm *57* and regulating spring *67*, the tension of which is adjusted by regulating nut *65*. When open, chamber *E* is in communication with the service reservoir and is subject to service-reservoir pressure. Assuming that usage or leakage has reduced service-reservoir pressure below normal, storage-reservoir pressure in chamber *F* forces supply-valve piston *54* to the right, compressing spring *58*, carrying supply valve *55* with it and uncovering port *b*, through which air passes directly into the service reservoir through passage *i*, *i*, raising the pressure of the service reservoir. This increase of pressure in the service reservoir, hence in diaphragm chamber *A*, continues until it becomes sufficient to overcome the tension of regulating spring *67*, which was adjusted to give at standard service-reservoir pressure. Diaphragm *57* then yields, allowing regulating valve *59* to be seated by spring *60*, thereby closing port *a* and cutting off communication between chamber *E* and the service reservoir. The pressures in chambers *E* and *F* then equalize by leakage past supply-valve piston *54*, and supply-valve piston spring *58*, previously compressed by the relatively high pressure in chamber *F*, now reacts and forces supply valve *55* to its normal position, closing port *b* and cutting off communication between the storage reservoir and service reservoir. A subsequent reduction in service-reservoir pressure reduces the pressure in chamber *A* and permits regulating spring *67* to force regulating valve *59* from its seat, thereby causing the accumulated pressure in chamber *E* to discharge into the service reservoir. The equilibrium of pressure on opposite faces of supply-valve piston *54* being thus destroyed, the higher storage-reservoir pressure in chamber *F* again forces it, with supply-valve *55*, forwards and recharges the

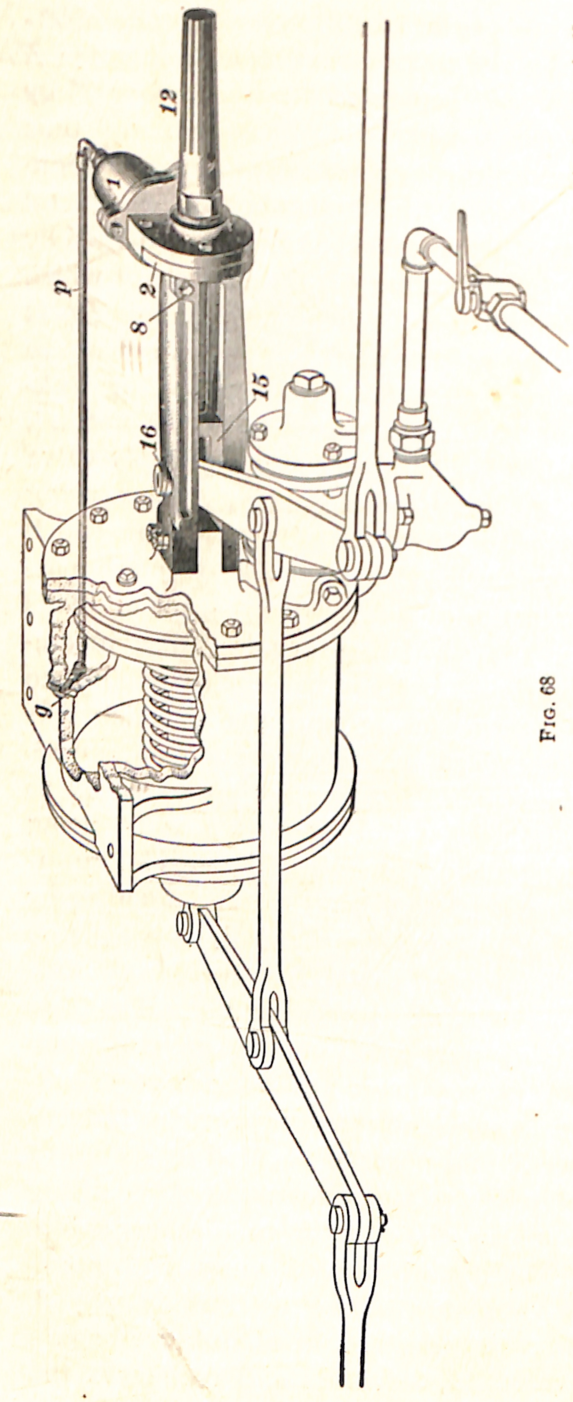


Fig. 68

service reservoir through port *b*, as before. This cycle of operations is repeated whenever usage or leakage reduces service reservoir pressure below the standard value.

70. The Automatic Slack Adjuster.—*Standing travel* is the distance through which the piston travels to apply the brake on a car that is standing; *running travel* is the distance through which the piston travels to apply the brake on a car that is running. Running travel is greater than standing travel and is due to slack in loose-fitting brasses, to the shoes pulling down on the wheels, to play between boxes and pedestals, to clearance between kingbolts and center castings, and to everything that increases lost motion in the brake rigging under the

influence of the motion of the car. Standing travel can be regulated by hand adjustment, and running travel can be indirectly governed, within limits, by allowing for the difference when adjusting the hand travel. Running travel can be actually regulated under working conditions by using a *slack adjuster*.

71. Fig. 68 is a general view of the Westinghouse **slack adjuster** applied to a brake cylinder, as indicated in the storage air-brake plan of Fig. 66. Fig. 69 illustrates details of the mechanism. The underlying principle of the device is that a hole is tapped in the brake cylinder and a small pipe *p*

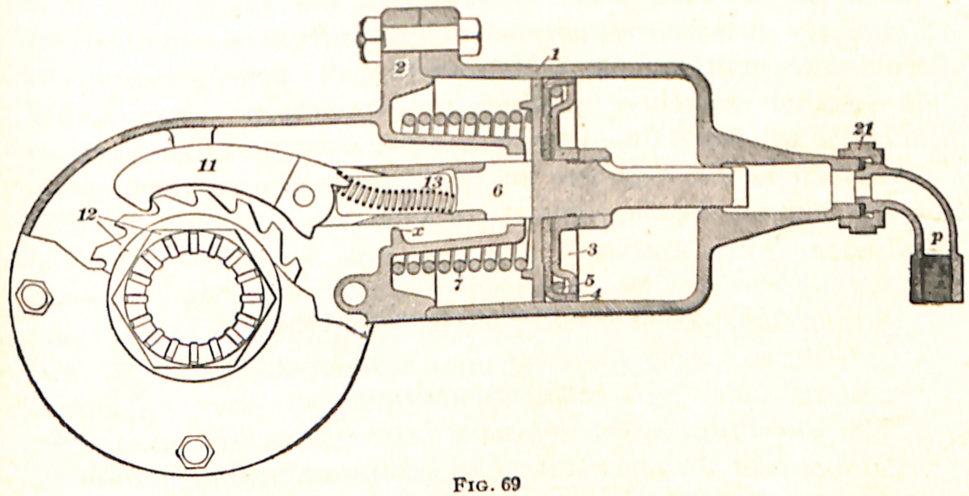


Fig. 69

screwed in it to connect the brake cylinder with the slack adjuster. When the piston travel exceeds a certain predecided amount, it uncovers the tapped hole to the live end of the brake cylinder, permitting some of the brake-cylinder air to pass into the small slack-adjuster cylinder, shown at *2*, Fig. 68, and in detail in Fig. 69.

In Fig. 69, admission of brake-cylinder air to the space behind piston *3* forces the piston and the attached pawl *11* to the left, the pawl dropping on to ratchet wheel *12*, which is mounted on a screw connected to crosshead *15*, Fig. 68. When release of the brakes places the brake-cylinder adjuster port on the atmospheric side of the brake piston, the air in

the adjuster cylinder escapes to the atmosphere and adjuster spring 7 forces piston *3* and pawl *11* back to normal position, the pawl turning ratchet *12* and screw part of a revolution; just before stopping, a heel on the pawl engages shoulder x, which raises the pawl clear of the ratchet wheel so that hand adjustment will not be interfered with. The result of this clockwise movement of the screw, Fig. 68, is to move the cylinder end of the brake lever nearer to the slack adjuster, thereby pulling all brake shoes nearer to their wheels so that the piston will not have to travel so far in order to apply them. To create considerable clearance so that a set of new brake shoes can be installed, the extension *12*, Fig. 68, is turned in a counter-clockwise direction; to take up slack rapidly by hand, extension *1* must be turned in a clockwise direction. If a set of new shoes is given proper clearance, the slack adjuster will keep the running travel correct throughout the life of the shoes. To get the best results, the two cylinder levers must make the same angle with the axis of the brake cylinder.

AUTOMATIC AIR BRAKES

INTRODUCTION

72. In train work, *automatic air brakes* are generally used because they are safer, especially on trains of more than two cars. If a train with straight air breaks into two parts, the air brake is useless and the hand-brakes must be applied on both sections. If the train has automatic air brakes, each section will come to a stop at about the same rate and there will be little danger of disaster. Again, comparatively long trains can be braked much more smoothly with automatic air because the brakes apply practically simultaneously on all cars, whereas with straight air there may be enough difference to cause bumping or stretching. In automatic air brakes, the air that does the braking is supplied from a small auxiliary reservoir on each car and the movement of the air from the auxiliary reservoir to the brake cylinder is controlled by a triple valve so that when

the engineer's valve is operated the brakes are applied to all cars simultaneously.

The automatic air-brake devices used on electric trains are in most cases the same as those used on steam trains, but, owing to the substitution of electricity for steam as a motive power, certain devices must be modified. In steam practice, the compressed air is supplied by a steam-driven air pump on the engine; the air is compressed into a main tank located on the engine and the pressure in the tank is controlled by a pump governor also located on the engine. On electric trains on which all motive power is developed on a single car, the arrangement is the same as on the steam train except that the air pump is driven by an electric motor and air pressure is controlled by an electric governor. Where each car of an electric train must be a complete motive-power and air-brake unit capable of operating alone or on any train combination, the arrangement is a little different. An automatic air-brake motor car has all the devices found on one equipped with straight air brakes with the addition of the auxiliary reservoir and triple valve, the functions of which can be understood by a consideration of Fig. 70. The only devices that have not been explained in connection with the straight air-brake equipment are the triple valve and the engineer's valve, which is a little different from that used on straight air cars. Fig. 70 is designed merely to illustrate the operating principles of automatic brakes and no attempt is made to show the actual details of the various parts; a complete description, including all the constructional features of the various devices, is beyond the scope of this treatise.

DESCRIPTION OF PARTS

73. The Triple Valve.—When valve *3* of the triple valve is in the position shown in the diagram, Fig. 70, air from the train pipe can pass into chamber L', thence through feed-groove *4* and chamber R to the auxiliary reservoir R_a. Train-pipe air will then feed into the auxiliary reservoir until its pressure is the same as that of the train

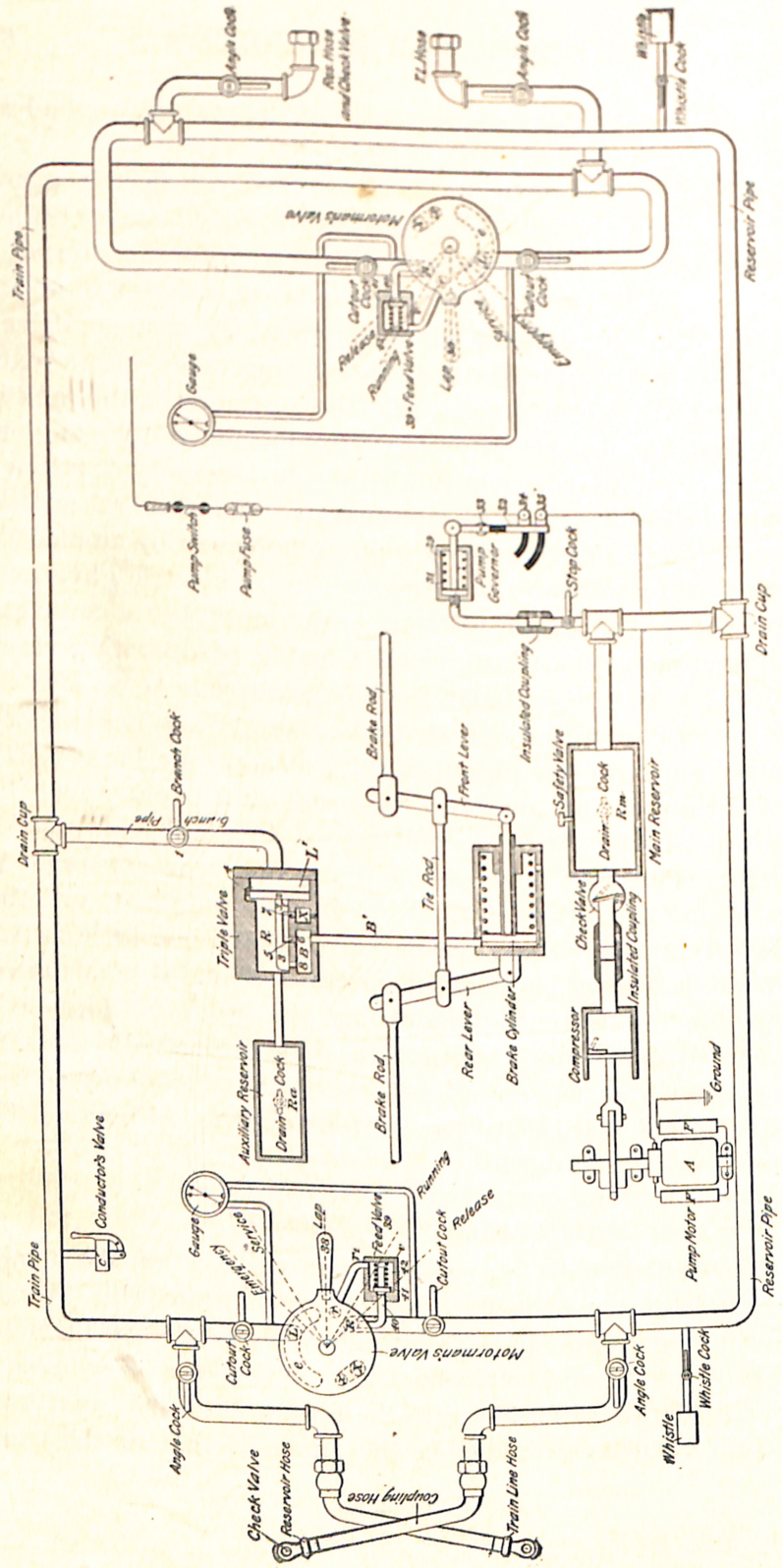


FIG. 70

pipe, under which condition the pressures are said to have *equalized*. The pressure in chamber R is then the same as in L' and the triple valve is said to be in *release position*, because the brake cylinder is in communication with the atmosphere through pipe B', chamber B, port *6*, cavity in slide valve *3*, port 7, and exhaust chamber and port X. If for any reason air is drawn from the train pipe, thereby reducing the pressure in the train pipe and in chamber L' of the triple valve, auxiliary-reservoir pressure in chamber R will force triple piston *2* and slide valve *3* to the right; this will first close feed-groove *4* so that auxiliary-reservoir air cannot flow back into the train pipe; then the flat part of the slide valve *3* will close port *6* and then open port *8* so that auxiliary-reservoir air can flow into the brake cylinder by way of chamber B and pipe B', thereby setting the brake. This is called *service position*, because it is used to produce a service stop. In order to release a brake that has been thus applied, it is necessary to raise the pressure in the train pipe, and hence in triple chamber L', above that in chamber R and the auxiliary reservoir, so as to force the triple piston and slide valve back to release position, to recharge the auxiliary reservoir.

74. The Engineer's Valve.—The engineer's valve used with an automatic air-brake equipment places the operations of raising or lowering the train-pipe pressure within the control of the motorman. The device marked motorman's valve, Fig. 70, is a conventional sketch showing the general principle. Exhaust ports X and x in the valve seat connect together and open directly to the atmosphere; ports R and r do not connect to each other except through *feed-valve 39*. Port R opens to the reservoir pipe and L to the train pipe. By means of circular cavity e in the rotary part of the valve, the motorman can establish any desired connection between the valve seat ports.

75. In the figure, the valve handle *30* is shown in *lap position*, the only position in which it can be installed or removed. Lap position is used when it is desired to hold

temporarily to the condition that has been established in the braking system. For example, if it is desired to hold a car or train on a grade, the train is stopped and the valve handle moved to lap position, in which all valve ports are blanked so that there can be no movement of air through the braking system.

76. If the valve handle be moved one notch to the right of lap position—to *service position*—cavity *e* establishes connection between train-pipe port *L* and service-exhaust port *x*, allowing train-line air to escape gradually to atmosphere. This gradual reduction of train-line pressure causes the triple valves to move to service position, resulting in a *service application* of the brakes throughout a train.

77. On moving the valve handle as far to the right as it can be forced (*emergency position*) cavity *e* connects train-line port *L* to emergency exhaust port *X*, allowing train-line air to discharge to atmosphere with a rush that causes the triple valves to move to emergency position where the auxiliary reservoirs equalize with the brake cylinders almost instantly, thereby immediately setting all brakes with full force. In the conventional triple valve of Fig. 70 no emergency attachments are shown.

78. Movement of the valve one notch to the left (*running position*) causes cavity *e* to establish connection between train-line port *L* and charging port *r*. In this position, if the difference between main-reservoir line and train-line pressures exceeds 20 pounds, main-reservoir pressure will lift feed-valve *41* against the feed-valve spring *42* and feed into the train line. Main-reservoir air will continue to feed into the train line until train-line pressure plus the tension of spring *42*, usually 20 pounds, is able to seat the feed-valve. The difference between main-reservoir and train-line pressures is called *excess pressure*. On steam trains, the governor maintains main-reservoir pressure at 90 pounds and the excess-pressure valves or feed-valves are set to keep train-line pressure at 70 pounds. On electric trains employing electric governors that do not cut in or out until a certain

minimum or maximum pressure is attained, however, the excess pressure is necessarily variable. The feed-valve is operative only on running position. If on any position usage or leakage of air reduces train-line pressure below its standard value, as soon as the engineer's valve is returned to running position main-reservoir pressure will open the feed-valve and recharge the train line to standard pressure. As long as the engineer's valve is on running position, all triple pistons are released and all brake cylinders connected to atmosphere so that any tendency of train-line or triple-valve leaks to cause brakes to creep on is offset by the ability of the main reservoirs to supply leaks through the feed-valve.

79. To release brakes promptly after an application, the valve handle is moved to the extreme left to *release position;* here cavity *e* covers ports *R*, *r*, and *L* and main-reservoir air rushes into the train line through the large and direct opening thus created. Train-line pressure being thus rapidly raised above that of the auxiliary reservoirs, the triple-valve pistons promptly move to release position, allowing the air in all brake cylinders to discharge to atmosphere.

FEATURES OF TRAIN HANDLING

80. Definitions.—The act of reducing train-line pressure is referred to as a *train-line reduction* or simply a *reduction*. A *service reduction* causes a *service application*, which produces a *service stop*. An *emergency reduction* causes an *emergency application*, which produces an *emergency stop*. An emergency reduction may be due to operation of the engineer's valve, as described, or to a train parting or a hose bursting. *Charging* the train line refers to bringing an empty train line up to standard pressure. *Recharging* the train line refers to restoring standard pressure reduced by making a reduction. *Overcharging* the train line refers to allowing its pressure to exceed standard value when recharging. Overcharging the train line tends to do away with *excess pressure*.

81. Making a Service Stop.—In making a stop, an initial reduction of 5 to 7 pounds is made; any less than this may be insufficient to move all brake pistons beyond their leakage grooves, in which case the air delivered by the auxiliary reservoirs through the triple valves to the brake cylinders is wasted. An initial reduction exceeding 7 pounds is not recommended, as it is liable to result in a shock to the train. In the single-application method of stopping, the initial reduction is followed by a series of lighter ones, the braking force being kept on until the train stops. In the two-application method, the initial reduction is followed by a series of lighter ones until the application is such that if held by lapping the valve, the train would stop several car lengths short of the desired point; before reaching this point, however, the brakes are released and the train permitted to roll into the station at reduced speed, when a mild graduated application will stop it at the exact point desired. A given total reduction followed by a full release constitutes one application irrespective of how many times the engineer's valve is moved to service position and back to lap to make the given total reduction. The two-application method is well adapted to close stops, where platform and car gateways must register. After making the first application, the valve is returned to lap position. The second application must follow the first so closely that if the valve is held on release or running position any longer than is necessary to release the triple valves, the train-line pressure will increase considerably above that in the auxiliary reservoirs, which will not have time to equalize through the small triple piston feed-grooves. This condition would mean a loss of air and time in making the second application, because the train-line pressure must be reduced below auxiliary-reservoir pressure in order for the triples to operate.

82. Making an Emergency Stop.—When danger requires the quickest possible stop, sand is applied to the rail and the valve is thrown to emergency position and *left there* until the train stops or the danger is past, because if thrown

to lap position too soon after an emergency reduction, rush of train-line air from the rear of a long train is liable to kick off the forward brakes; on short trains, such action is not probable. Emergency stops may be produced not only by regular operation of the engineer's valve, but by the parting of a train, bursting of an air hose, or by operation of a safety valve, called the *conductor's valve*, that is located in a conspicuous place in passenger coaches and is supposed to be operated by any one in case of trouble not known to the motorman.

83. Value of Excess Pressure.—Excess pressure is provided to insure prompt movement of the triple pistons to release position. After an application, train-line pressure is below auxiliary-reservoir pressure and the triple pistons are on lap position. To force the pistons of a lot of triple valves in good order to release position, standard train-line pressure is sufficient; but when a triple shows a tendency to stick, it is often necessary to admit main-reservoir pressure of 90 pounds into the train line. A tank of given size will hold more air, by weight, at 90 pounds per square inch than 70 pounds, so that carrying 20 pounds excess pressure virtually amounts to increasing main-reservoir capacity without increasing the size of the main reservoir. By carrying an excess pressure, air is efficiently stored at higher pressure and efficiently used at a lower pressure sufficient to meet all requirements.

84. Releasing Brakes.—Releasing brakes consists in recharging the train line by placing it in communication with the main-reservoir line through the engineer's valve. When recharging the train line, great care must be taken not to overcharge the train line and thereby destroy excess pressure. If the engineer's valve is left on release position too long, main-reservoir and train-line pressures will equalize. To avoid such a condition, the valve is left on release position just long enough to release the triples when it is placed on running position, so that the recharging may be completed through the excess-pressure valve.

ELECTRIC BRAKES

85. Various methods have been devised for operating brakes on electric cars by means of electricity, but so far **electric brakes** have been used but little in comparison with air brakes. They are all more or less complicated and have not proved to be as reliable or as easily controlled as compressed-air brakes. In most systems the current for operating the brakes is obtained by changing the connections so as to make the motors act as generators, thus making use of the energy stored in the car to supply the power used in braking. This is an economical method, but it throws additional work on the motors, and if they are already loaded to the limit it may cause overheating. This source of current supply allows the application of the brakes even though the trolley may be off the line, but it is obvious that the car can never be brought to a dead stop on a grade by means of such brakes because in order to generate current the motors must be in motion; the hand-brake must, therefore, be applied after the car has slowed down. In the American electric brake, described later, current is taken from the trolley so that the car can be stopped and held on a grade by means of the electric brakes alone.

GENERAL ELECTRIC BRAKE

86. The **General Electric brake** is dependent on the generator action of the car motors. Current generated by the motors is passed through coils wound on a disk-shaped magnet supported by the motor frames; opposite these magnets are armatures in the form of iron disks mounted on the car axles and rotating with them. Excitation of the stationary magnets causes them to attract the rotating armatures, thereby producing friction effective in stopping the car. The value of the braking current is within the control of the motorman up to a limit fixed by an automatic limit switch, which weakens the motor fields when the braking current exceeds the value for which the limit switch is set. The brake-controlling devices are within the regular operating

controller and consist of extra cylinder segments and fingers, together with an auxiliary switch that insures that the motors may always have their fields and armatures connected in the proper relation to generate, irrespective of the position of the reverse handle and of the direction of the car movement. The brake devices are put into action by advancing the controller handle beyond the regular off-position, an amount dependent on how hard it is desired to apply the brake.

WESTINGHOUSE ELECTRIC BRAKE

87. The **Westinghouse electric brake** also depends on the generator action of the car motors, but the brake itself differs widely in method of application from the one just described. The braking current passes through a coil c, Fig. 71, provided with a core terminating in poles to which are attached track shoes a, a'. Normally, the track shoes are supported a short distance from the rails by springs d, d', but

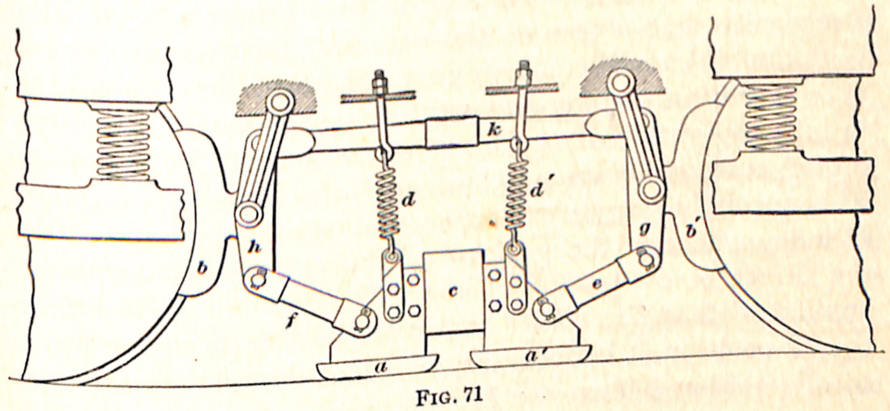


FIG. 71

on sending current through coil c the track shoes are drawn to the rail with great force, thereby tending to stop the car; simultaneously, through levers e, f, g, h, and rod k attached to the track shoes, the regular car brake shoes b, b' are forced against their respective wheels, thereby applying a second braking force.

The electrical connections are so arranged as to permit of using either the car starting coil or the car heaters as

resistance for regulating the braking current. By using the heaters for brake-current regulation, the heat dissipated is utilized for car-heating purposes. In summer, this system of regulation would make a car uncomfortable, so that on closed cars a switch is provided to enable either the heaters or starting coil to be used.

AMERICAN ELECTRIC BRAKE

88. The **American electric brake** has several features not found on other electric brakes. At speeds above 4 miles an hour, the braking current is due to the generator action of the motors and to a small line current. At lower speeds, the braking current is supplied from the line, a special relay automatically determining which source of power is to be used. The braking pressure applied to the regular car brake shoes, is due to a solenoid with a plunger so designed that the pull is practically constant throughout its travel. The braking current is applied through a controller standing beside the regular controller, the two being so connected electrically that abuse of the car equipment is prevented. With the brake applied, the regular car controller cannot introduce operating current, and with the power controller applied in full, application of the brake controller will interrupt the motor current before any braking force acts. On account of a special separate excitation feature, the braking ability is independent of the position of the reverse handle and of the direction of motion of the car. Should the brake be applied without the power controller having been thrown to the off-position, it is necessary to return the power controller to off-position before the brake can be released and motor current again introduced.