headlight to be used on a car that has two five-lamp circuits. The removal of the headlight from either end of the car

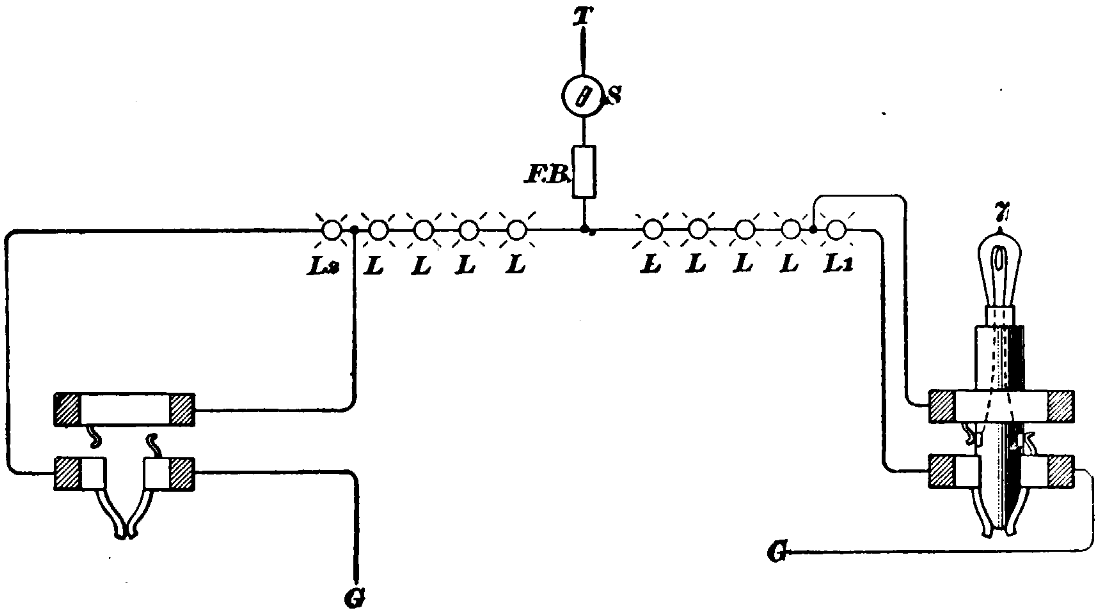


FIG. 57.

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

BRAKES.

INTRODUCTION.

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

53. On cars rigged with hand-brakes, the brake handle is the force arm of the first lever of the series of levers that press the shoes against the wheels. Fig. 58 is a sketch of the parts involved in this lever. The amount of pull on the rod depends on how much longer the brake handle is than the radius of the drum and on how much of a pull the motorman is able to exert at *P*. Suppose that the brake handle is 14 inches long. Call the diameter of the drum $1\frac{1}{2}$ inches. When a brake chain made of $\frac{3}{8}$-inch stock is wound up on this drum, the average diameter of the wrap of chain will be about $2\frac{3}{4}$ inches; one-half of this diameter, or $1\frac{3}{8}$ inches, is the short arm of the lever of which 14 inches is the long arm, making the leverage of about 10 to 1. Some men are able to pull on a brake handle much harder than others. We will assume that the average man can exert a maximum pull of 200 pounds. The pull exerted on the brake rod will then be 2,000 pounds.

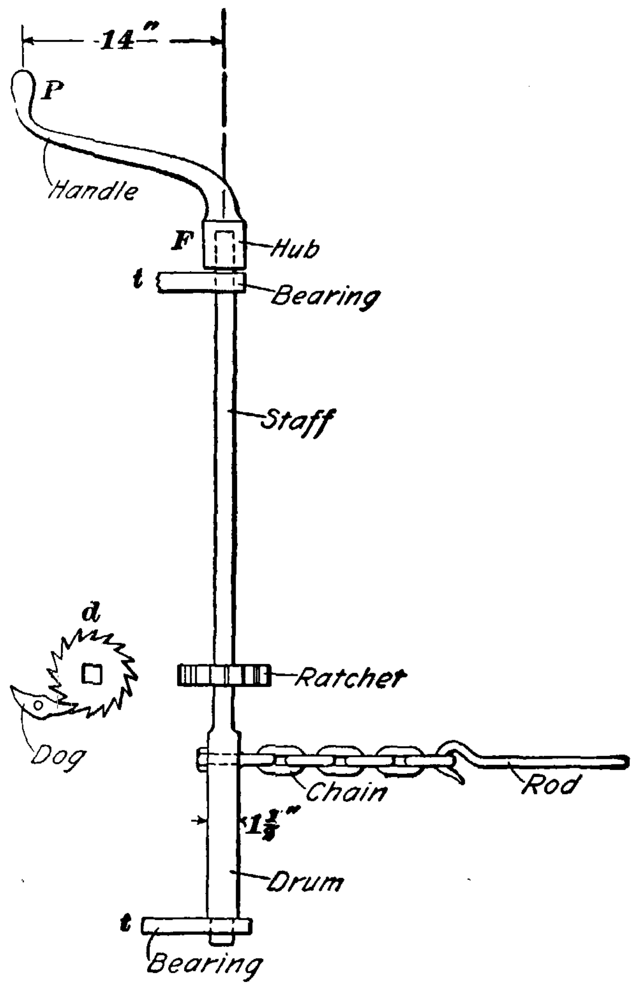


FIG. 58.

54. Shoe Pressure.—The amount of pressure required to brake a car depends on the weight and speed and on the number of wheels that have shoes applied to them. If a car has eight wheels and the brakes are applied to four of them, the pressure per brake shoe must be the same as would be necessary were all the wheels supplied with shoes, because the braked wheels carry only one-half the total weight of the car; the maximum pressure to be applied to a wheel depends on how much weight the wheel supports. To avoid sliding, the pressure applied to a wheel should be a little less than the weight it supports.

55. Friction.—The amount of pressure necessary to cause a wheel to slide depends, of course, on the amount of friction between the shoe and wheel. How much of the pressure applied to a wheel is useful in stopping a car depends on the nature of the material of the shoe and wheel. Some car wheels are soft and others hard; the same is true of brake shoes. For a given hardness of wheel, a soft shoe will give more friction at a given pressure than a hard one, but it wears out sooner. Also, the amount of friction between a shoe and wheel changes with the speed of the car. The friction increases as the speed decreases, so that at high speeds a much greater pressure can be applied without sliding the wheel than at low speeds; from this it follows that in bringing a high-speed car to a stop, the brake should be eased up a little as the car slows down. Under different conditions of speed and brake shoe and wheel composition, the friction between the shoe and wheel varies from 15 to 35 per cent. of the applied pressure; that is to say, if a pressure of 10,000 pounds were applied to the shoe, only 15 per cent. of this possibly might be accounted for as retarding the car.

56. It is a well-known fact that the friction between a shoe and wheel is independent of the amount of surface exposed between them. For a given total pressure applied, the effect of varying the surface of a brake shoe is simply to vary the pressure per square inch; this is true when the wheel is perfectly round and the shoe truly concentric with it. There is, however, a growing tendency to use long brake shoes, because they not only tend to keep the wheel round, but since the pressure per square inch is less, they last longer.

57. Condition of Rail.—An important factor to be considered on trolley roads is the condition of the rail. The **T** rail on steam roads is mostly laid in the open country and offers very little inducement to the accumulation of snow and slush upon its top. Where a **T** rail is used in trolley-road construction, it has the same advantages. Trolley roads have paving conditions to contend with and must use a girder rail, whose flat top and open groove are very inviting to foreign substances.

When the rail is slippery, it is an easy matter to apply too much brake pressure, thereby causing the wheels to slide and make flat spots on them. To offset the disadvantage of a slippery rail, it is the custom to use sand. The use of sand greatly improves the rolling friction between wheels and rail, but most managements make the mistake of sanding only one rail instead of two. With sand on one rail, the rolling friction averages 30 per cent. of the weight on the wheel.

58. When a car rests upon a rail, there is a certain amount of friction between the wheels and rails, and this friction increases as the weight on the wheels increases. It would take a certain number of pounds pull on the rim of a wheel to turn it against the friction of the rail without moving the car. Also, when the car is in motion, if, in the effort to stop the car by means of the brakes, the latter are set up so tight as to lock the wheels and cause them to slide, the friction between the wheels and rails tries to make the wheels roll again. It is this friction that in the previous article was said to be 30 per cent. of the total weight of the car. The total pressure to be applied to the brake shoes depends on the leverage of the brake rigging, on its condition, and on the pull on the brake handle. The fraction of this pressure that actually retards the motion of the car depends on the friction between the shoes and wheels.

59. Fig. 59 shows a very 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 pieces fixed to the side frames of the truck; they are called *brake-beam castings*. Fig. 60 shows the general idea. A is the slide casting, B the beam, and F the truck member that supports the casting. Equalizer rods r, r (see Fig. 59) connect to equalizer bars E, E and are erroneously said to equalize the pressure on all brake shoes. Under the most favorable circumstances, they partially equalize the pressures against the two wheels on the same axle. Each equalizer rod ends in a jaw J, to which the equalizer bars are rigidly connected, but in which the brake beams move freely. Fig. 61 shows the construction. R is the rod; J, the brake jaw; B, the beam; and E, the equalizer bar. In Fig. 59, 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 E can move and F_1 is a pin in common to L and B. In the diagram, the brakes are shown to be off and the shoes have been pulled away from the wheels by the release springs. One end of each

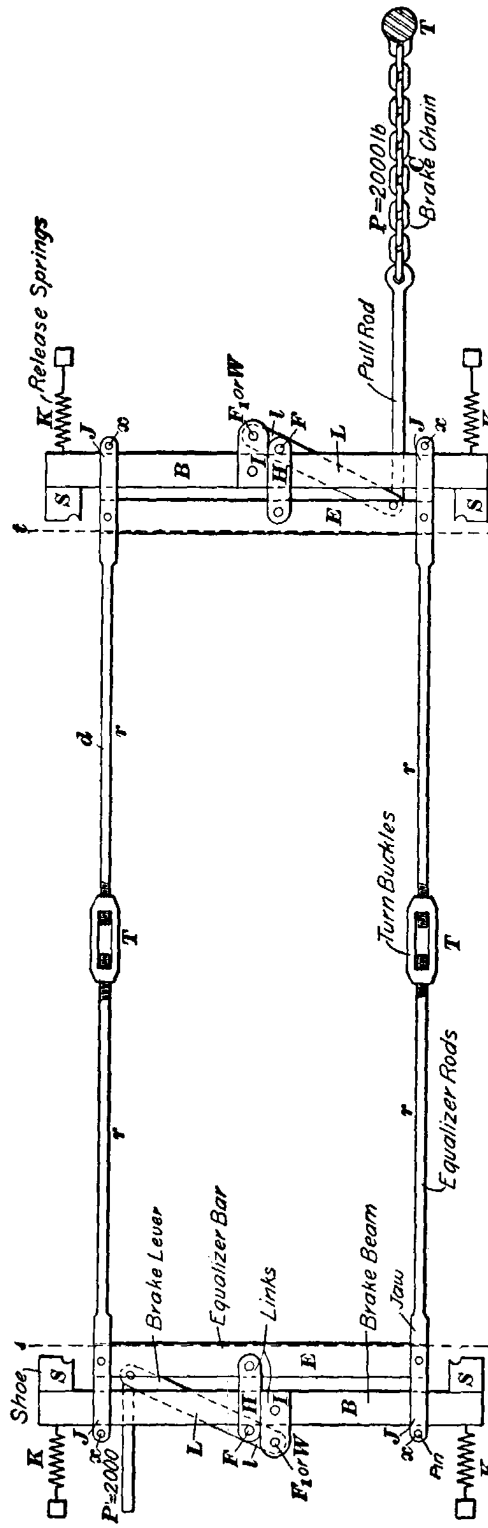


FIG. 59.

spring is fixed to a lug on a car truck and the other end to the brake beam or shoe head. Brake slides wear badly and give trouble in winter time 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 final 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. 59. The force exerted on the pull rod P draws the brake beams B, B together, and thus presses the shoes S, S against the wheels.

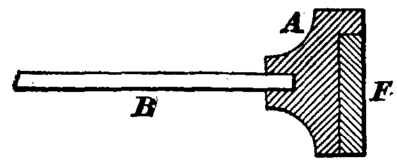


FIG. 60.

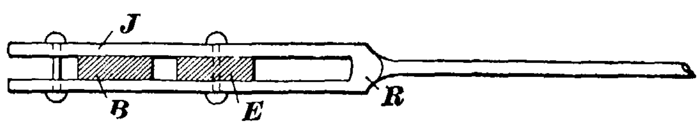


FIG. 61.

POINTS ON CARE OF RIGGING.

60. The main points to be observed in caring for brakes on single trucks are the following: See that all brake-staff bearings are kept lubricated. They should be oiled frequently, using but little oil at a time, to avoid soiling the passengers' clothes. The brake-staff ratchet wheel should not be allowed to run with teeth missing nor should the dog be allowed to have a blunt point; both should be renewed as soon as defective. Particular care should be taken to see that the action of the ratchet brake handle is perfect. If the handle ever fails to catch while being applied and the clicking noise emitted on release seems to be weak, it means that the dogs inside the handle hub have become blunt or that the springs pressing them into the ratchet have become weak; such a condition should be reported at once, as it is liable to cause a serious accident.

61. Should the brake handle appear to be much harder to turn at one point of its revolution than at all others, it probably means that the brake staff is bent. To avoid this, the brake staff should be well supported on its lower end, where the greatest strain comes. The brake chain should be fastened to the staff, so that it will wind upon the staff and not on itself; otherwise, the leverage will decrease as the brakes are applied. In case there are any tripod brackets to support the lower end of the brake staff, care should be taken that the legs of the brackets are so disposed as not to interfere with the winding up and paying out of the brake chain.

62. Inspection of Parts.—All brake-chain fastenings should be inspected every day. Every small amount of wear weakens a chain, and it is only a question of time when it will get weak enough to break. Defects are often caused by some rod or lever rubbing on a part of the car or some other device. When a brake rod is interfered with, the friction not only puts extra work on the motorman, but it may also put so much work on the release springs that they become useless. The constant rubbing will weaken the rod, so that in course of time it will break. All rods and levers may clear everything when the car is light and interfere with each other or some part of the motor rigging when the car is loaded. A rod may clear a wheel of one type and interfere with another whose dish is greater. An excessive end play in the axle collars will let the motor over against the brake rods. An excessive load on a car whose springs have become weak may let the rods down on top of a gear case or motor. In placing or inspecting a set of rigging, all these points must be kept in mind, making due allowance for the effects in the increased weight on the car body, weakening of the truck springs, and wear on the moving parts of the brake rigging. All turnbuckles, brake slides, fulcrums, and, on double-truck cars, the strap hangers, in which parts the brake rigging slides, should be kept lubricated. Release springs should be renewed when they become too weak to pull the shoes to off-position.

DOUBLE-TRUCK HAND-BRAKES.

63. Single-truck and double-truck brake riggings differ in two and sometimes three respects. A double truck consists of two single trucks, each of which has a complete set of brakes of its own. Both of these trucks revolve around independent centers, so that means must be provided to preserve the efficiency of the brakes whatsoever may be the angle that either truck makes with the center line of the car body. The third feature of difference depends on whether all the wheels on a truck are the same size or not. If they are, constituting what is known as an ordinary double truck, each of the eight wheels on the car has the same weight resting upon it, so that each shoe must have the same pressure applied to it. If, however, the truck has two large wheels and two small ones, constituting the so-called maximum-traction truck, the truck is so disposed that the large wheels support from 60 to 70 per cent. of the weight of the car.

64. Fig. 62 shows a truck rigging, the action of which explains itself. If the shoes are properly adjusted, a pull of 2,000 pounds at P will give each shoe a pressure of 5,000 pounds, if the leverage of PFW is 10 to 1, bearing in mind that the figure shows the rigging on only one side of the truck.

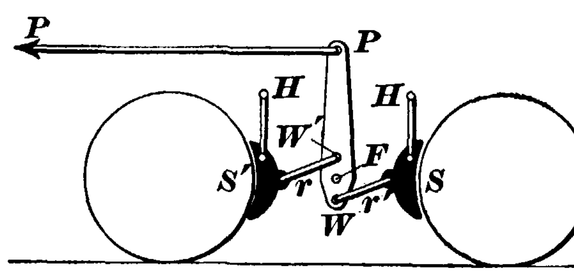


FIG. 62.

65. Fig. 63 shows two such truck riggings adapted to a double truck; the long lever PP is secured to the car body through fulcrum F, which is, therefore, stationary. Fig. 64 shows the device used to compensate for the rotation of the truck on curves. C, C are two pieces of steel bent to an arc to suit the rotation of the truck. These bent pieces of steel are variously called "circle bars," "arch bars," and "existing arches," and the pull rods from the respective trucks connect to their ends. Tension rods X, Y carry on their ends a grooved wheel through which the

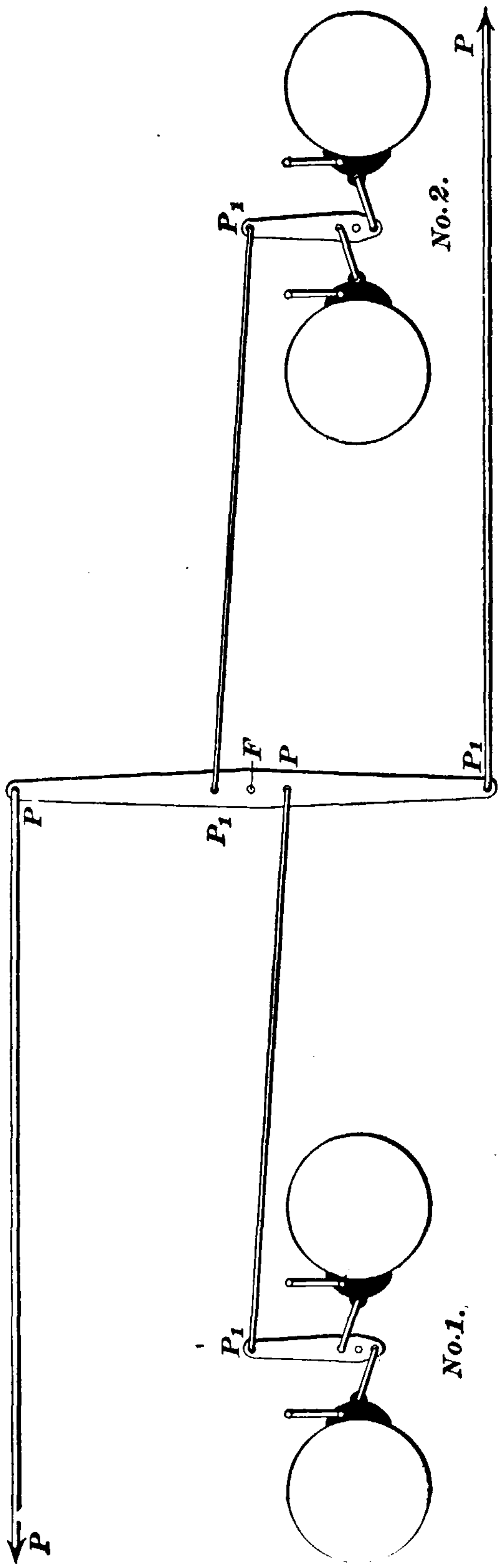


FIG. 63.

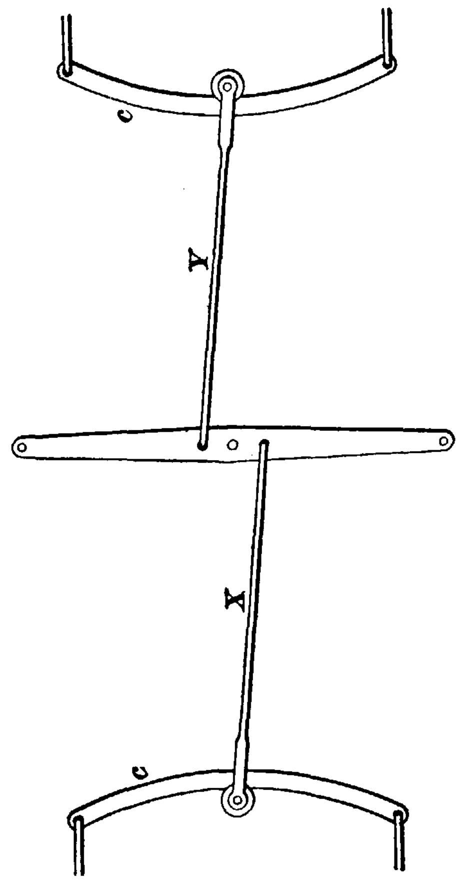


FIG. 64.

circle bars roll as the truck rotates, thereby preserving the position of the brake rigging.

66. Fig. 65 is a diagrammatic sketch of one-half the rigging used on a maximum-traction truck, where most of the weight is on the large wheels, so that most of the pressure must be applied to them. *PWF* is the truck brake lever whose fulcrum is fixed to the truck at *F*. A rod *R* runs from *W* to the brake beam on the larger wheel; at *x* the

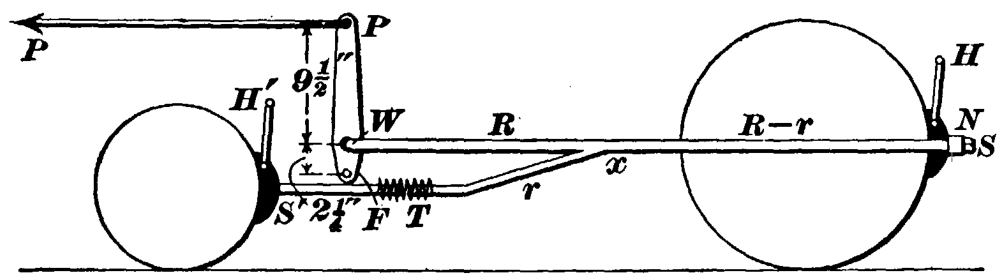


FIG. 65.

rod branches, the branch rod *r* returning to the brake beam on the smaller wheel. The branch rod is not continuous, but acts through a spring *T*, whose resistance can be regulated by means of a nut not shown in the diagram. The resisting force of spring *T* and its amount of compression are an exact measure of the pressure exerted on shoe *S'*.

AIR BRAKES.

CLASSIFICATION.

67. Air brakes, as used on electric cars, may be divided into two classes, known as *straight air* and *automatic air*. In both classes, the brakes are set by allowing compressed air, stored in a reservoir, to expand into a *brake cylinder*, thus moving the piston and operating the brake levers. In a straight air equipment, the devices are such and are so arranged that the compressed air passes directly from the reservoir into the brake cylinder without passing through any automatic device. In an automatic air equipment, however, this is not so. Figs. 66 and 67 are diagrams illustrating the difference. In Fig. 66, when valve K_1 is open, pump P stores air in reservoir R, until gauge G shows the desired maximum pressure; K_1 is then closed. To apply the brake, valve K is opened; the air in R then expands into B, pushing on piston P_1 and shoving S against W. To release the brake, valve K is closed and K_2 opened, allowing the air in B to escape to the atmosphere, so that release

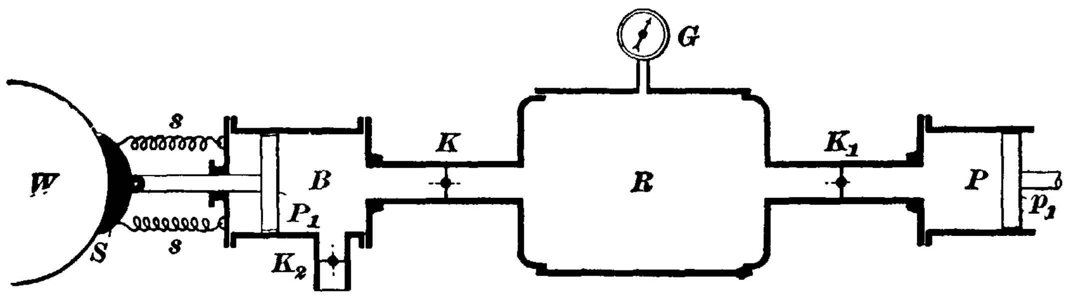


FIG. 66.

springs s, s can pull the shoe from the wheel. Valves K and K_2 should never be opened at the same time, as this allows air to pass from R direct to the atmosphere, causing a great waste of air. In actual practice, valves K, K_1, and K_2 are operated by a single handle in such a way that wasteful connections cannot well be made.

68. In. Fig. 67, the main reservoir M is kept stored by a pump, both being on the engine or motor car. On each coach or trailer is an auxiliary reservoir R, a device called a triple valve, and a brake cylinder B. M, R, and B connect to the triple valve, as shown. The triple valve is automatic in action and has three duties to perform. It must make an opening between M and R, so that M can store air in R; it must connect R and B to apply the brake; and it must connect B to the atmosphere to release the brake. Piston p of the triple valve can move back and forth. Chamber A always carries main-reservoir pressure. The chamber on the left of piston p always carries auxiliary pressure. If the pressure in M exceeds that in R, p is forced to the left, as shown in the figure. In this position, air from M leaks through groove g and stores R until M and R are at the same pressure. To apply the brake, the pressure in the pipe connecting M

to the triple valve is reduced by letting out some of the air in it. This makes the pressure in chamber *A* less than that in

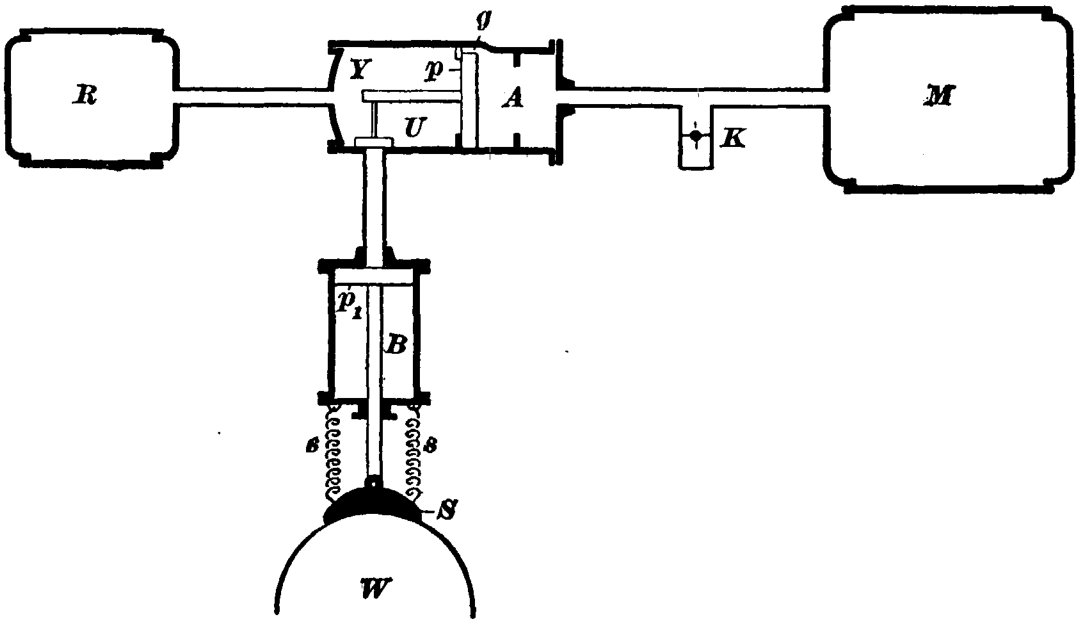


FIG. 67.

the auxiliary reservoir, thereby moving piston *p* to the right, uncovering the pipe leading to *B*, and opening up communication between *R* and *B*; this forces down piston p_1 and sets the brake. To release the brake, the motorman, by means of his operating valve, reestablishes communication between *M* and its connecting pipe, thereby raising the pressure in chamber *A* above that of the auxiliary reservoir *R*, so that *p* moves to the left and again closes communication between *R* and *B*. At the same time, by means of a valve, also operated by the stem of piston *p*, but not shown in the figure, communication is established between cylinder *B* and the atmosphere, thus letting the air out of the cylinder and allowing the release springs to release the brakes.

Automatic air brakes are used on long trains, because they allow the brakes to be set on all the cars at the same time. For ordinary trolley cars, where only single cars or a single car and trailer are operated, the straight air equipment is simpler and safer than the automatic air. The use of automatic air on electric cars is, therefore, confined principally to elevated and underground roads, where heavy trains of considerable length are operated.

69. Straight Air Equipment.—Fig. 68 shows the general arrangement of a Christensen straight air equipment as used with a trolley car and trailer. The outfit consists of an air compressor that is driven by a small geared motor; this compressor is usually well cased in and hung from the under side of the car. The motor that drives the compressor is controlled by an automatic governor that starts the motor when the pressure gets below a certain amount and stops it when the air has been compressed to the required pressure, usually about 60 pounds per square inch. The compressor stores the air in reservoir R, and from this reservoir it is allowed to flow into the brake cylinder by means of the operating valves at either end of the car. K, K are cut-out cocks in the reservoir pipe and K_1, K_1 are cut-out cocks in the brake-cylinder pipe. The cocks K_4, K_4 are for connecting on other cars, as indicated. The motor circuit of the compressor is controlled by two snap switches K_3, one at either end of the car, so that the motor may be cut out from either end or so that the motor may be controlled by hand in case anything goes wrong with the automatic governor. At each end of the car there is a gauge, provided usually with two hands; a red hand to indicate the reservoir pressure and a black hand to indicate the pressure in the brake cylinder.

70. The Brake Valve. — The brake valve, generally called the **engineer's valve,** is a device by means of which the motorman applies and releases the brake. It is located on the car platform between the hand-brake and the controller. The brake valve has three duties to perform. It is provided with a handle that controls the performance of these duties. In one position of the handle, the reservoir and the brake cylinder are connected, thereby setting the brakes. In a second position, the brake cylinder and the atmosphere are connected, thereby releasing the brakes. In a third position, all air passages are blanked so that there can be no movement of air in any direction.

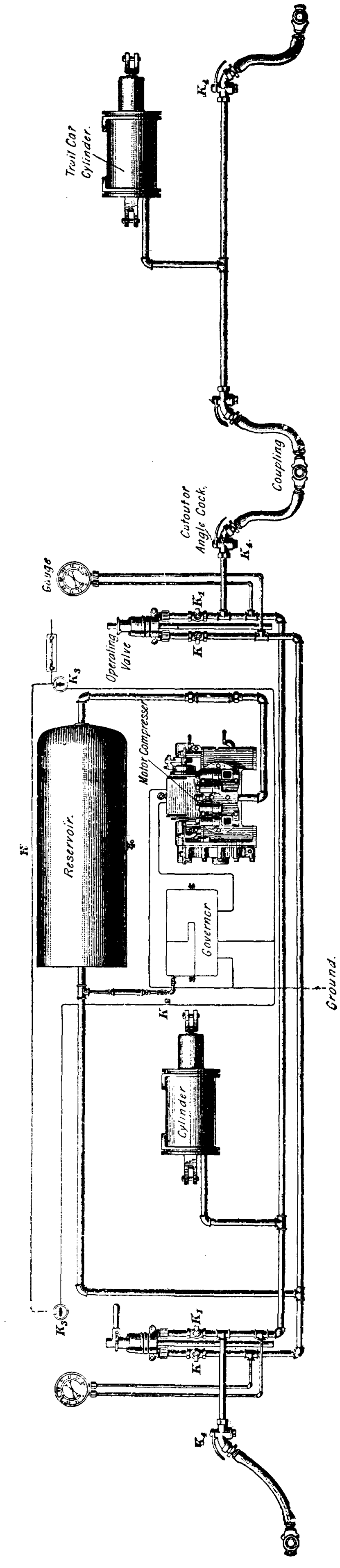

Trail Car Cylinder.
Gauge
Operating Valve
Cutout or Angle Cock.
Coupling
Reservoir.
Motor Compressor
Governor
Ground.
Cylinder

FIG. 68.

71. Fig. 69 shows the nature of the operations that the brake valve performs. B_1, E_1, and R_1 are three pipes leading from the brake cylinder, atmosphere, and reservoir, respectively, to the brake valve; on top of the valve body is a cap (b) that turns around b_1 as a center and has in it a slot c c. In the position shown in the diagram, the handle points front and the ports to which E_1 and R_1 lead are covered by the under side of the valve cap and do not, therefore, communicate with each other or with the port leading to pipe B_1. If, however, the valve handle is moved to the right, the slot in the cap connects ports B_1 and R_1 and air passes from the reservoir to the brake cylinder and shoves piston p to the dotted position p_1, thereby setting the brakes. If the cap handle is moved back to the vertical position, all the ports are again blocked and the air in the brake cylinder must remain there and keep the brakes set. By moving the valve handle to the left, ports B_1 and E_1 are connected, thereby allowing the air in the brake cylinder to escape to the atmosphere and permitting the release springs to pull the piston back to its normal position. The engineer's valves made by different manufacturers differ considerably in detail, but the operations that they perform are essentially those just outlined.

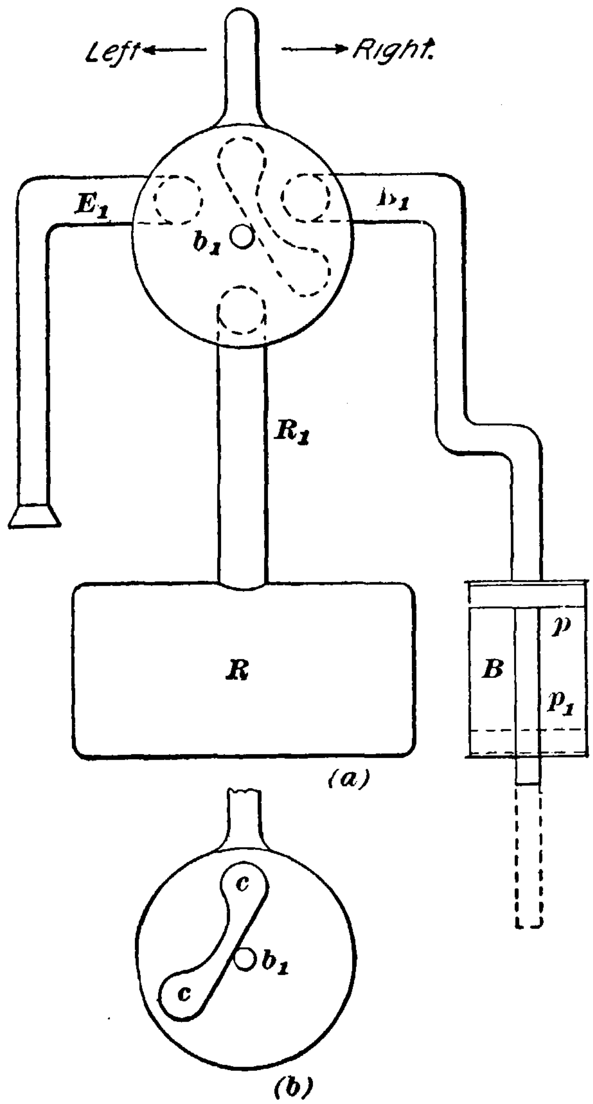


FIG. 69.

72. Positions.—Fig. 70 is a top view of the Christensen valve as it appears on a car. The dotted circles indicate the exhaust, reservoir, and brake-cylinder connections, as marked. There are five positions—namely, *lap*, *service stop*, *emergency stop*, *slow release* and *running*, *quick release*. The brake handle can be removed only on the *lap* position. In the *lap* position, the handle points towards the motorman; all ports are blanked so that none of the three pipes can communicate with each other. If there is any air in the brake cylinder, it is held there.

To make a **service stop,** the operating handle is moved to the right into the **service** position. In the service position, a small opening is created between the reservoir and

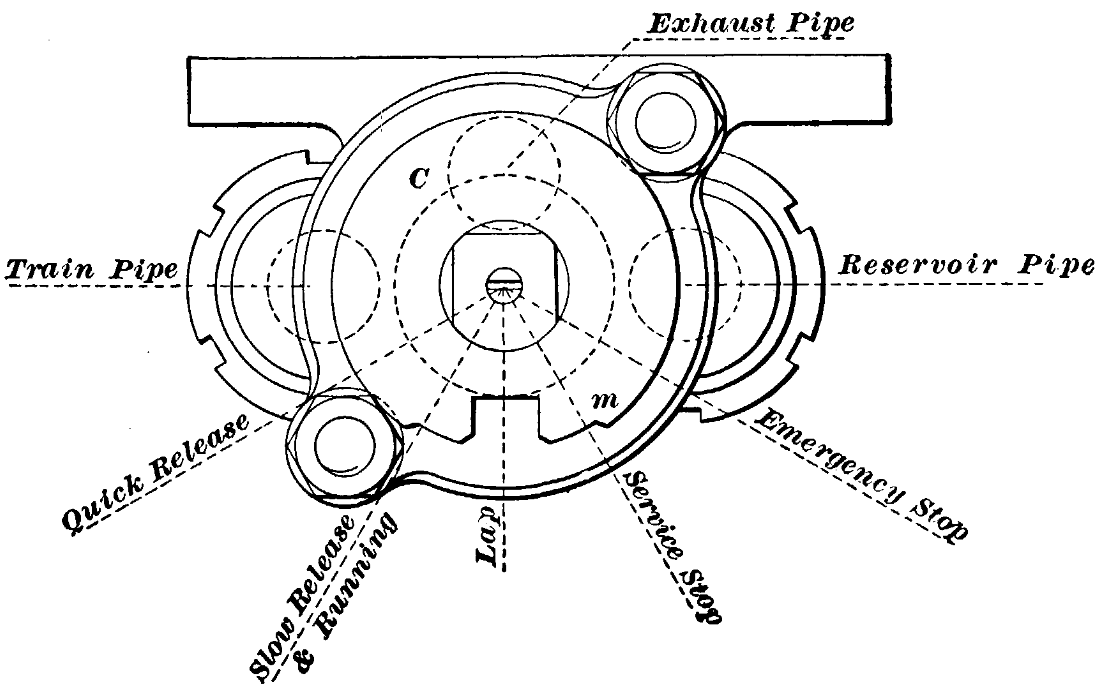


FIG. 70.

brake cylinder, so that compressed air passes from the reservoir into the cylinder; as this opening is small, the flow of air is gradual and the degree to which the brakes are set depends on the length of time that the valve is allowed to rest in the service position. If in making a service application, the motorman finds that the car is going to stop too soon, he releases the brakes a little by letting a little air out of the brake cylinder; this is done by throwing the operating handle to the *slow-release position.*

In the **slow-release** position a small opening is created between the brake cylinder and exhaust pipe, thereby letting some of the compressed air in the brake cylinder escape into the atmosphere; this lowers the pressure in the brake cylinder and tends to release the brakes. If the handle is left on the slow-release position too long, the brakes will release entirely.

When the valve handle is moved to the **full-release** position, the air in the brake cylinder escapes to the atmosphere in a single puff; this gives the release springs a chance to pull the brake piston, levers, and shoes to the release position.

If the operating handle is moved to the right as far as it will go, a full and unobstructed passage is opened between the reservoir and brake cylinder, thereby allowing the full reservoir pressure to act upon the brake piston and immediately setting the brakes with full force. This position is known as the **emergency** position.

THE GOVERNOR.

73. Wherever a motor-driven compressor is used, means must be provided for starting the compressor when the pressure in the reservoir becomes too low and for stopping it when the pressure reaches the value at which it is intended to operate the brake.

74. The Christensen Governor.—A top view of the automatic governor or "automatic" used on the Christensen air-brake equipment is shown in Fig. 71. *L* and *R* are electromagnets; *A A* is an armature or plunger that can slide back and forth between the magnets and carries an arm to which the finger *K* is fastened by means of the insulating block *I*. When an electric current is made to pass through the magnet *L*, the plunger or armature *A A* is pulled to the extreme left-hand position. Finger *K* makes contact with finger *K'*. When a current passes through the magnet *R*, the armature is pulled to the right and the motor circuit of which K and K' are a part is opened. D is a coil through which all current that goes to the motor must pass; this coil acts as a magnetic blow-out to extinguish the arc that forms between K and K' before it can burn or blister them and thereby impair their electrical contact.

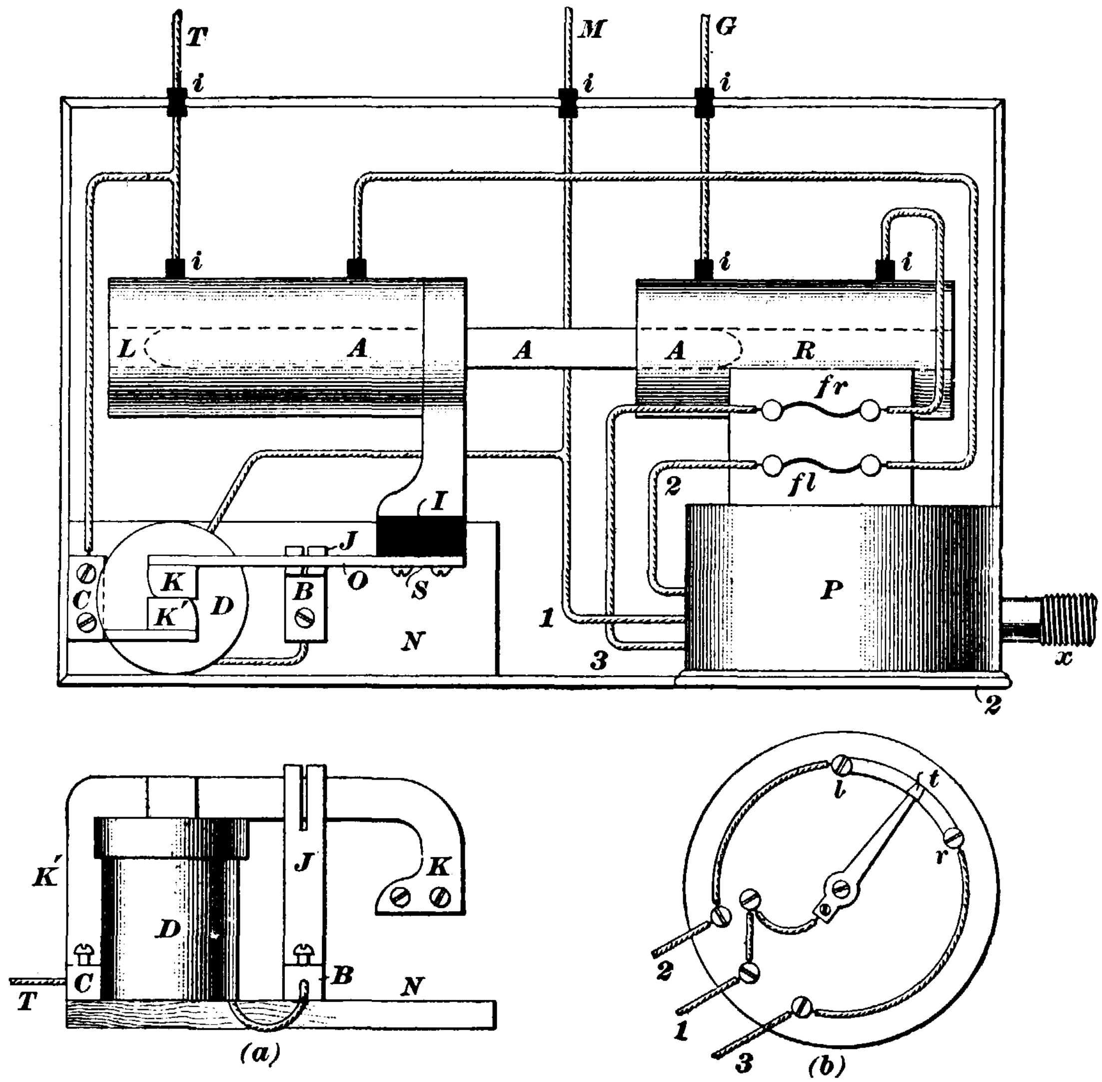


FIG. 71.

When fingers K, K' are pulled apart, the open circuit lies between terminals C and B. In other words, when the fingers K and K' touch each other, the current coming in on the trolley wire T takes the path T–C–K'–K–J–B–D through the blow-out coil and to the wire M that leads to the motor circuit.

75. P is the *regulator* that determines which of the two magnets R and L shall get current and these determine whether or not the compressor motor shall run, because when *L* gets a current, *K* and *K'* touch; but if *R* gets a current, they do not. *P* is a contact maker or circuit opener and closer, whose action is exactly the same as that of a pressure gauge. The hand of the gauge, instead of being used to indicate pressure on a scale, is made to carry on its end a little carbon knob *t*, Fig. 71 (*b*), that plays between contact buttons. These contact buttons are lettered *l* and *r*, because when *t* touches button *l*, magnet *L* gets a current; and when *t* touches *r*, magnet *R* gets current. Pipe connection *x* goes to the reservoir or to one of its pipes, as shown in Fig. 68; f_r, Fig. 71, is a fuse in circuit with magnet *R* and f_l is a fuse in circuit with magnet *L*. One end of fuse f_r leads to connection *3* in the rear of the regulator and from there to contact button *r*. The other end of the fuse goes to magnet *R*. One end of fuse f_l goes to post *2* on the rear of the regulator and thence to contact button *l*; the other end of the fuse goes to magnet *L*. The middle contact post *l* on the rear of the regulator connects to the hand that carries the carbon knob *t*, and since the hand moves, the connection is made by means of a very flexible wire. Post *l* also connects on the outside to the wire that runs from the blow-out coil *D* to the motor circuit. All shaded parts marked *I* or *i* are hard-rubber insulating parts. Wires *T*, *M*, and *G* are the main governor wires leading to the car trolley wire, the pump motor, and the car ground wire, respectively.

Fig. 72 is a diagram of the connections of the governor. The regulator hand *t*, Figs. 71 (*b*) and 72, is so adjusted that when there is no pressure in the reservoir, and therefore no force within the air lobe that operates it, a spring forces the carbon knob against contact post *l*. Suppose that there is no air in the reservoir and that it is necessary to start the pump to get up pressure; the carbon knob *t* touches the contact *l*. Current comes in at *T* to point *X*, Fig. 72; if magnet *L* was the last one to operate and the armature *A A* is, therefore, in its extreme left-hand position, as indicated in Fig. 71 (*a*), fingers *K* and *K'* make contact, thereby connecting points *B* and *C*, Fig. 72, so that the current splits at *X*;

part of it takes the path *X–C–B–D–Y–M–M'–W–Ground* and starts up the pump motor, and part of it takes the path *X–L–*f_l*–l–t–Y–M–M'–W–Ground* through the left-hand magnet coil *L*, exciting it. In this particular case, where the armature *A A* and the finger *K* are already at the extreme left-hand end of their travel, magnet *L* does not do anything. Suppose that at the time the pump switches were closed, armature *A A* happened to be so far to the right that fingers *K* and *K'* failed to touch each other. In this case, when the current gets to *X*, it cannot go through the pump

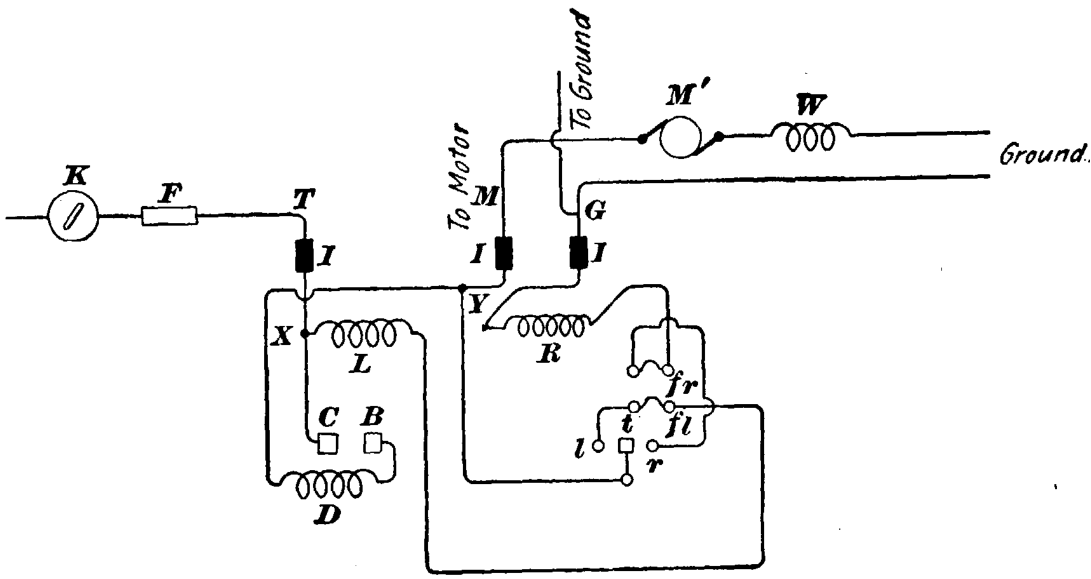


FIG. 72.

motor and start the pump, because the circuit is open between *B* and *C*. But it does take the path through the left-hand magnet, which then pulls the armature *A A* to the left, causes *K* and *K'* to touch, and starts the pump. It is true, as can be seen in Fig. 72, that the current that passes through magnet *L* to pull *A A* over to the left also must pass through the pump motor to reach the ground; but on account of the resistance of magnet *L*, this current is too small to start the motor.

76. As the pressure in the regulator increases, due to an increase in the reservoir pressure, contact *t* is pulled away from contact post *l* and interrupts the flow of current through magnet *L*, Fig. 72. Armature *A A* still remains at the extreme left-hand end of its travel; contact fingers *K*, *K'* still touch each other; and the pump motor still works, for there is as yet no influence brought to bear to pull the armature to the right.

77. As the pressure in the reservoir increases, the carbon knob *t* moves slowly away from contact *l* towards contact *r*. As soon as it touches contact *r*, current from the trolley wire takes the path *T–X–C–B* (remember that fingers *K* and *K'* on contact blocks *C* and *B* still touch each other) *D–Y–t–r–*f_r*–R–G*. Magnet *R* pulls armature *A A*, Fig. 71, quickly to the right, pulls fingers *K* and *K'* apart, and stops the pump motor. At the same time, since coil *R* gets its current from the motor-circuit trolley wire at point *Y*, which is on the negative side of the contact breaker *K K'*, as soon as the circuit opens between *K* and *K'*, magnet *R* can no longer get any current and can exert no pull on *A A*, which, however, lies there until a fall in the pressure causes the knob *t* to drop back on contact *l*, once more pulling *A A* to the left.

78. The Standard Air-Brake Governor.—The governor used by the Standard Air-Brake Company is somewhat different in principle from the Christensen governor just described. Fig. 73 is a general view of the device and Fig. 74 shows the electrical connections. In Fig. 73, *S* is a heavy spring that acts against the reservoir pressure in cylinder *C* to determine the position of lever *L*, which, by means of a connecting-rod, moves switch blade *14*, Fig. 74, in and out of contact jaws *13* and *15*. *d* is an iron-enclosed electromagnet that has

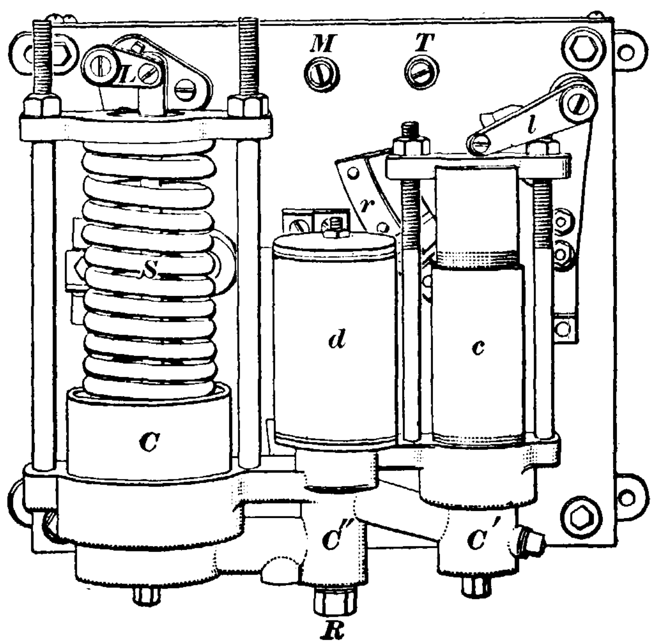


FIG. 73.

within it a plunger that is free to move down or up, according as *d* is excited or not. In chamber C'', Fig. 73, is a spring that pushes up on a cone-seated pin valve. Chamber C'' admits air to cylinder C' when the pin valve is in the proper position and cylinder *c* carries a piston whose stem operates lever *l* to move a contact arm over plates *r*, *r*, Fig. 74, thereby cutting resistance in or out of the motor circuit, as occasion may demand. The reservoir pipe is connected at fitting *R*, Fig. 73. The piston in cylinder *C* is pressed down by spring *S* and up by the reservoir pressure below it. Spring *S* is so designed that it can keep the piston down and switch *13–14–15*, Fig. 74, closed when the reservoir pressure acting against it is less than 50 pounds to the square inch. As soon as the reservoir pressure gets above 50 pounds, it begins to compress spring *S* and moves lever *L* counter-clockwise. Immediately a rod, also connecting lever *L* to the switch mechanism, starts to pull on this mechanism, which is so designed that it does not actually pull the switch out until the pressure reaches 60 pounds per square inch. The switch is pulled out by a spring that snaps it out to avoid any arcing. When the reservoir pressure is below 50 pounds, the piston in *C*, Fig. 73, is at the lower end of its travel and the switch is in, so that the pump motor runs and raises the pressure. As soon as the pressure gets above 50 pounds, it compresses the spring *S*, raises the lever, opens the switch, and stops the motor at 60 pounds.

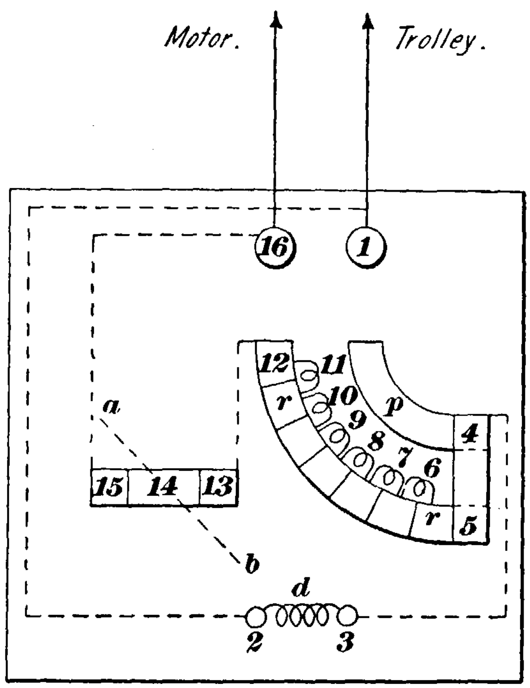


FIG. 74.

79. This arrangement alone would constitute a governor, for the pump is started when the pressure reaches normal value. But the Standard people do not approve of starting even a series motor at frequent intervals, by placing it dead across the line without any resistance in ahead of it.

80. With this governor, whenever the motor is started, a resistance is placed in series with it. As stated before, there is a spring in chamber C'', Fig. 73, that ordinarily presses up on a double-seated pin valve and closes all communication between chamber C' and the reservoir. A spring keeps the piston in cylinder *c* at the lower end of its travel when there is no air pressure admitted to chamber C' to force up the piston. In this position, lever *l* is down, as shown in Fig. 73, and contact arm *4–5*, Fig. 74, is in the position shown; all resistance is in.

81. The connections are shown in Fig. 74; post *1* takes the wire from the pump-motor snap switch and fuse box and is also connected to post *2*, to which one terminal of coil *d* also connects. Post *16* connects to one jaw of main switch *13–14–15*, and plate *12* of the series of resistance plates connects to the other jaw of the switch. When the switch is closed, as shown in the figure, the spring blade *14* connects jaws *13* and *15*; but when the switch is open, the blade takes the position indicated by the dotted line *a b* and no current can get from jaw *13* to jaw *15*. Post *3* connects to plate *p*. If switch *14* is closed, current comes in on post *1*, takes the path *1–2–3–4–5–6–7–8–9–10–11–12–13–14–15–16*, on through the pump motor to the ground. All resistance is cut in, as contact arm *4–5* is on the first plate, which position is caused by the piston in cylinder *c* being at the lower end of its travel, thereby pulling down the lever *l*, Fig. 73.

82. Operation.—Now, when the air in the reservoir is up to standard, spring *S* is somewhat compressed by the standard pressure under the piston on which it sets, switch *14* is open, and the pump is stopped; also, there is no air under the piston in cylinder *c*, because the spring in chamber C'' presses up on the pin valve and closes it. As soon as an application of the brakes or leakage causes the pressure in the reservoir to fall below 45 pounds per square inch, spring *S* pushes down the piston and stem and closes switch *14*, Fig. 74, allowing the pump motor to start.

Since resistance arm *4–5* is in the position shown in Fig. 74, all resistance is in and the starting current is small. The moment switch *14* closes, the starting current passes through coil *d* also and pulls down its core. The core presses down on top of the pin valve harder than the spring in chamber *C''*, Fig. 73, presses up; the result is that the valve is pushed off its seat, air is let into chamber *C'*, which raises the piston and stem connections to lever *l*, moves contact arm *4–5* clockwise, until it gets to plate *12*, where all resistance is cut out and the pump motor runs at full speed. As soon as the reservoir pressure reaches standard value and switch *14*, Fig. 74, opens, magnet *d* becomes dead, the spring in chamber *C''*, Fig. 73, once more closes the inlet end of the pin valve, the compressed air in the cylinder *c* escapes to the atmosphere, and the piston stem, lever *l*, and resistance contact arm *4–5* resume their normal positions.

THE BRAKE CYLINDER.

83. Fig. 75 is a sectional view of a brake cylinder. *4* is the piston; *13*, the hollow piston stem; *8*, the release spring; *2*, the front head; *3*, the back head; *1*, the cylinder body; *12*, the head bolts; *11*, the bolts for securing the packing to the piston; and *6*, *7*, the forks through which pass bolts *15* and *16* and around which turn the brake levers.

84. Operation.—Fork *6* is stationary; fork *7* moves back and forth with the push rod *P*, which moves with the brake levers. When air is let in at the right-hand end of the cylinder, piston *4* is forced to the left, carrying with it push 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 put on release position, letting all the air in the cylinder pass to atmosphere, spring *8* returns piston *4* and piston stem *13* to the normal position. Since fork *7* and push rod *P* are independent of piston 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 so 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 action of spring *8*. The travel of the brake piston should be kept within the limit prescribed by the brake company. After this limit is passed, the side pressure of the push rod *P* on the hollow stem *13* may be great enough to bend the rod or split the stem.

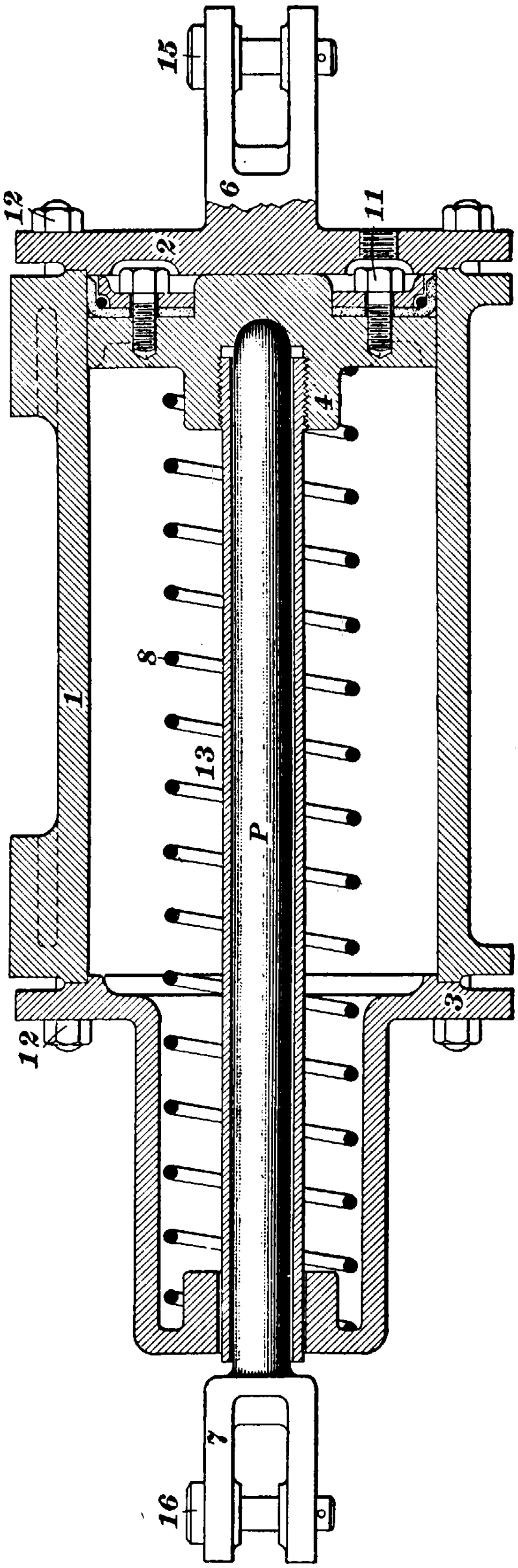
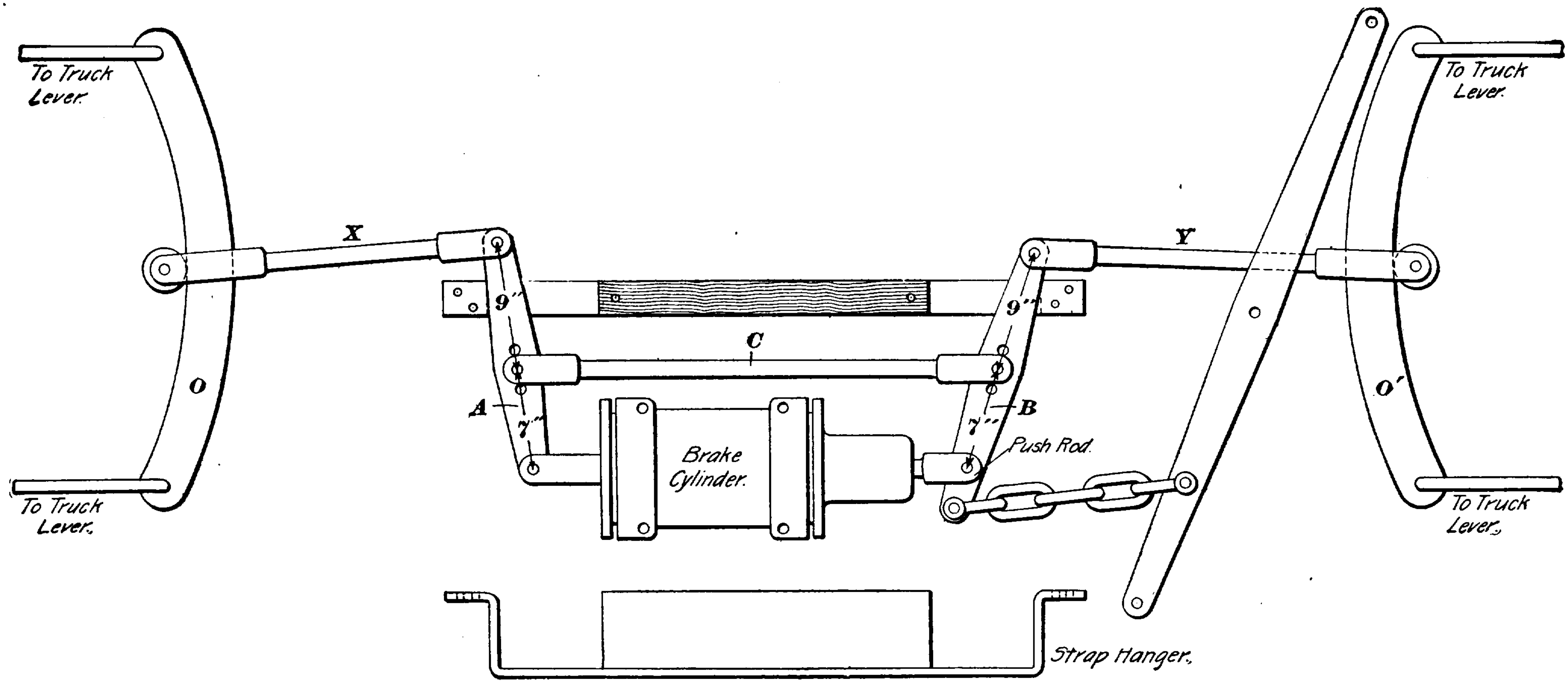


FIG. 75.

LEVER SYSTEM.

85. Fig. 76 shows a system of air-brake levers recommended by the Christensen Company. The diameter of the brake piston is in this case 6 inches and its area, in round numbers, is 28 square inches. Supposing that the reservoir has a pressure of 60 pounds per square inch and that full pressure is let into the cylinder, the total pressure on the piston that shoves on



To Truck Lever.
To Truck Lever.
X
O
9"
C
A
7"
Brake Cylinder.
9"
B
7"
Push Rod.
Y
O'
To Truck Lever.
To Truck Lever.
Strap Hanger.

FIG. 76.

the push rod and sets the brake is $28 \times 60 = 1,680$ pounds. *A* and *B* are the two levers that apply the brake; one end of *A* is fixed to the back head of the cylinder, the other end attaches to the tension rod *X*. One end of *B* connects with the push rod and the other end with the tension rod *Y*. Levers *A* and *B* are also connected through the tension rod *C*. Air admitted to the cylinder causes the push rod to move to the right, carrying with it the lower end of lever *B*. Using rod *C* as a fulcrum, lever *B* pulls on rod *Y*. Using rod *Y* as a fulcrum, lever *B* pulls on rod *C*.

When the hand-brake is used, the push rod is pulled in and out of the hollow piston that holds it. It will be noticed that the air brake and hand-brake operate in the same direction, so that if the air brake were applied with the hand-brake already partially set, there could be no danger to the motorman or the brake rigging.

THE ELECTRIC BRAKE.

86. Electric brakes are operated by making the motors act as generators to supply the necessary current. They may thus be operated no matter whether the trolley wheel is on the wire or not and do not take any additional current from the power station. In order that the brakes may take hold, the car must be in motion; hence, electric brakes cannot hold a car on a grade, although they may bring it nearly to a standstill. To hold the car, the hand-brakes must be applied. The electric brake that has so far been most largely used is that manufactured by the General Electric Company; we will, therefore, describe it briefly.

87. Fig. 77 shows the brake used on a motor car. It consists of a cast-iron ring split horizontally and held together, as shown, by bolts. As indicated by the dotted lines, there are magnetizing coils *C*, *C* in each half of the ring. Each coil consists of 32 turns of No. 8 wire. The sectional view shows how the coils are embedded in the iron and held in place by pouring in lead *P*, *P*, the insulation of the coil being protected from the hot lead by a thin layer of asbestos, not shown in the figure. The wearing plate *W*

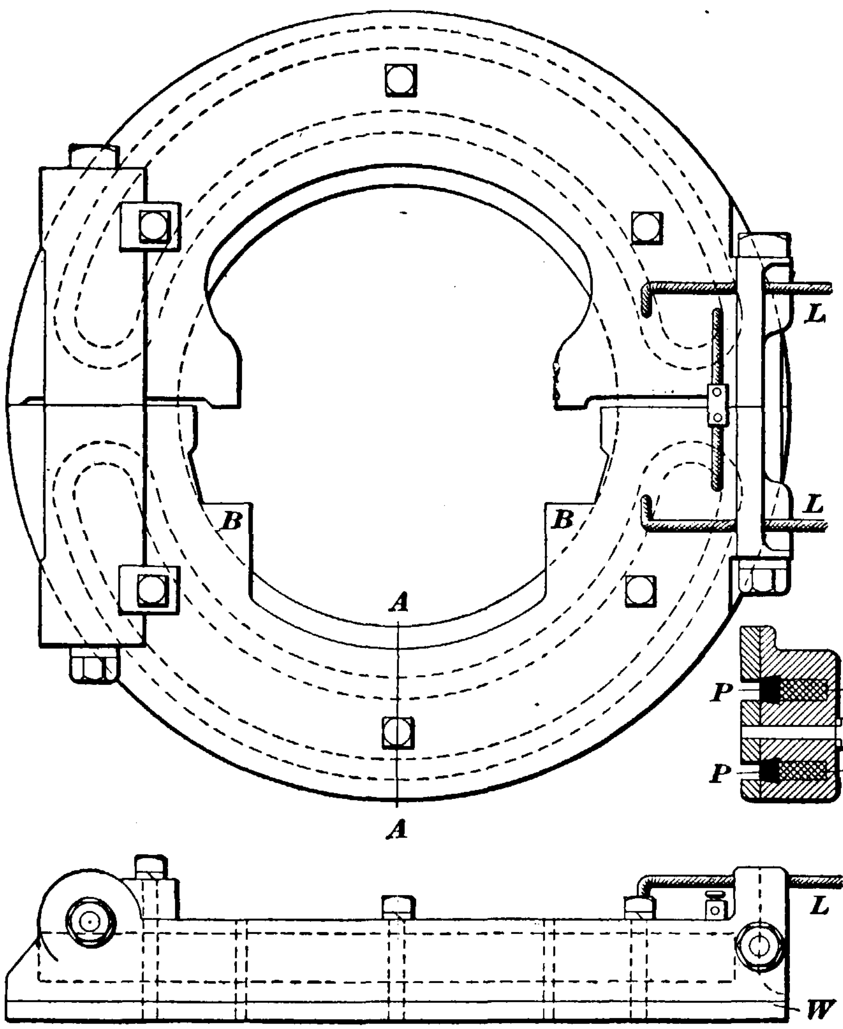


FIG. 77.

is in two pieces, one on each half of the brake ring and held on by capscrews. The two magnetizing coils are in series, connection with the car wire being made by means of leads *L*.

88. Fig. 78 shows the manner of *support*. The motor-bearing cap *C* has two projecting horns *A*, one behind and the other in front of the car axle. Lugs *B*, Fig. 77, of the brake ring rest on these horns, and thus the brake is held close to the disk *S* that turns with the axle. Setscrew *M* is used to take up the wear in the disk and ring. The ring has $\frac{1}{32}$ inch end play, but cannot rotate at all; hence, when it is magnetized, it draws itself over, clutches disk *S*, and tends to prevent its turning, thereby acting as a brake. Both the disk and ring are provided with wearing plates *W*.

So far as the motorman is concerned, the addition of the brake attachment does not add complications to either his cares or operations. On the main controller drum is a neutral position; on one side of this position are the power

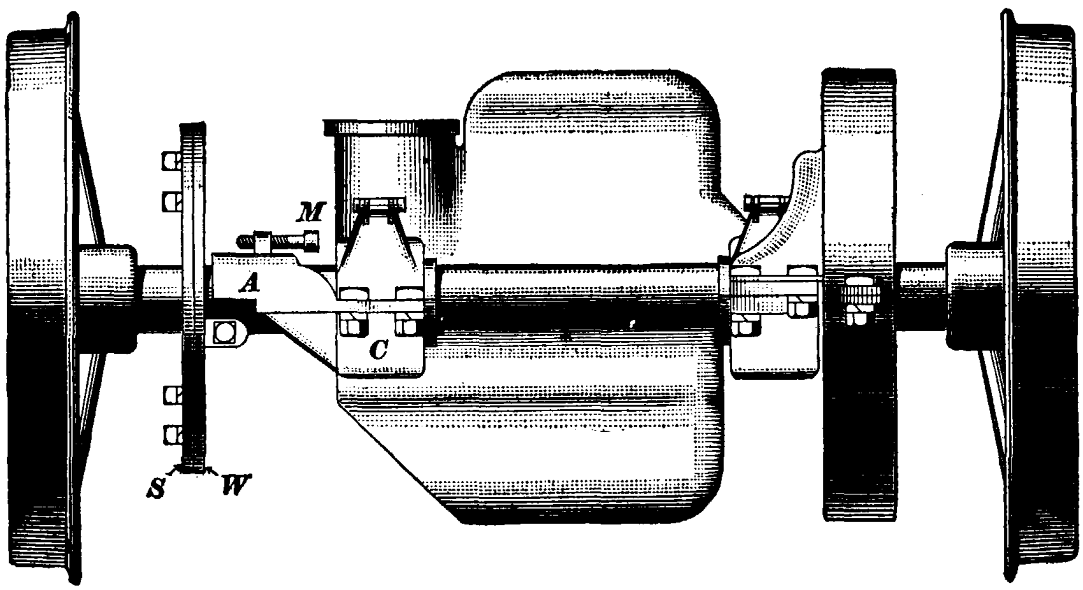


FIG. 78.

contact tips and on the other the brake contact tips. To start the car, the controller handle is operated as usual; to throw the current "off," preparatory to making a stop, the handle is thrown to the off-position, as usual; to apply the electric brake, the handle is simply kept moving past the off-position. To release the brake, the handle is returned to the off-position.

THE CONTROLLER.

89. The Main Drum.—The main drum is shown in the left-hand upper corner of Fig. 79. This drawing shows the connections for electric brakes used with a four-motor equipment with the B6 controller. There are 11 rows of contact tips. All tips that are marked with the same letter are metallically connected and the subjoined figure indicates the position on which the tip comes into action For example, PA_1 indicates that the tip is a power tip, that it is a part of the A drum casting, and that it comes into action on the first power position. PA_{10} is a power tip on the A casting and comes into action on the tenth power position. BA_4 is a brake tip of the A casting and comes into action on the fourth brake position. All the tips marked A are connected; if the A is preceded by a P, it is used in applying the power to start the car ; if it is preceded by a B, it is used on a brake position to stop the car. Thus it will be seen that some of the castings have tips, such as PA_1 and BA_2, etc., in common to applications of both the power and the brake, but are not in use at the same time. On the left of the main drum are shown the 11 main-drum fingers, T, R_7, R_6, R_5, R_4, R_2, B, R_7, *8*, E_1, and G. On the right of the main drum, these fingers are reproduced, not because there are actually two rows of fingers, but simply to make it easier to trace current paths; therefore, no wires are run to these fingers. When the car is being started, the student will imagine the main-drum contacts to move towards the left-hand row of fingers; when it is stopped, the drum moves towards the right-hand row. Thus on the first power notch, fingers T, R_2, B, and *8* make contact on the left-hand end of the drum; on the first brake notch, fingers B, E_1, and G touch the right-hand end of the drum. The row of enclosed numbers, beginning at *1* on the left and running up to *12*, shows the positions used in applying the power; the row beginning at *1* on the right shows the positions used in applying the brake. There is, therefore, a portion of the main drum, between power position *12* and brake position *6*, not touched by the fingers at all. This untraversed space is dictated by the width of the lug on the controller top; when the controller handle gets to the full multiple position, the twelfth position, one side of the lug stops it; when it gets to the last brake notch, the sixth position, the other side of the lug stops it.

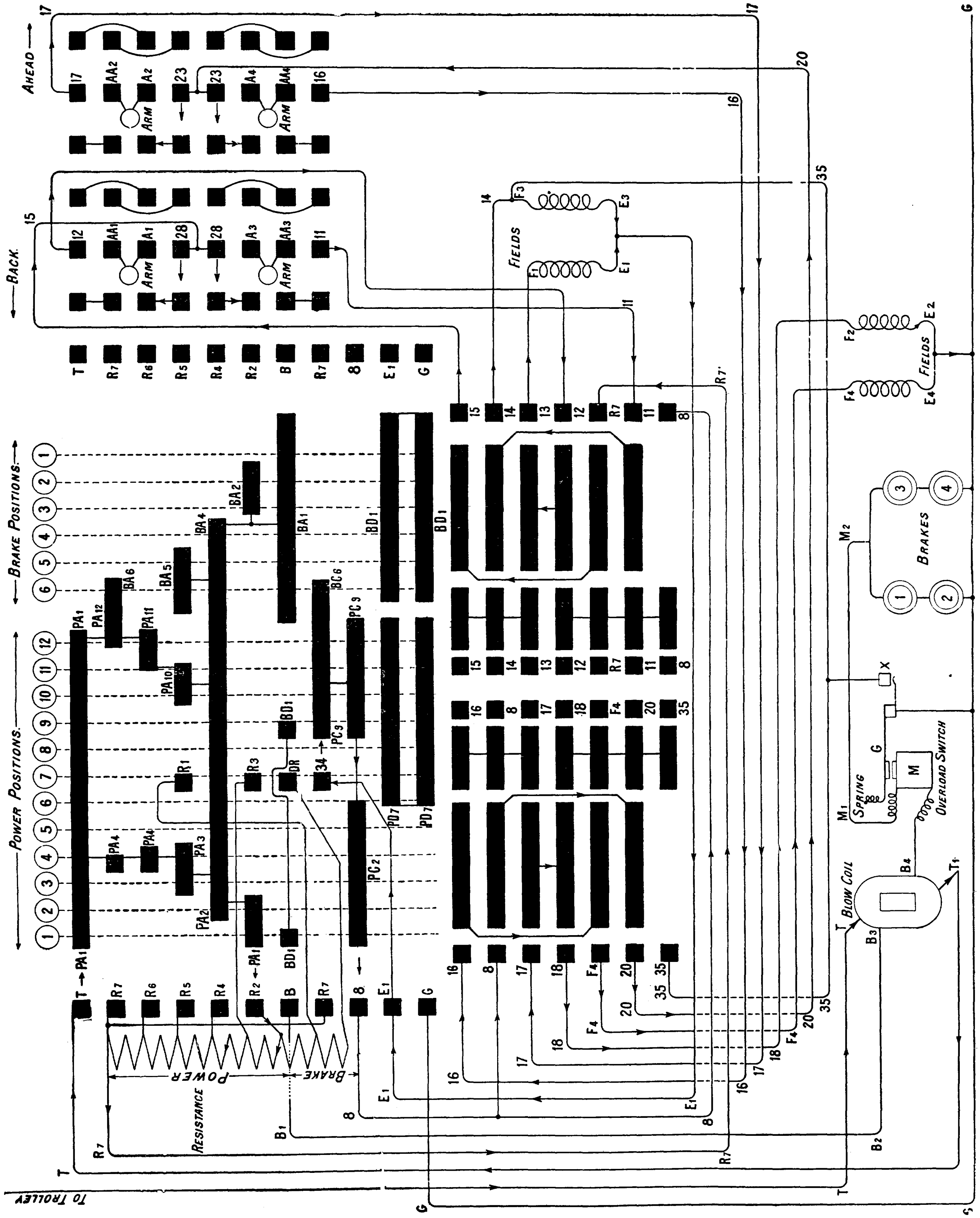

Ahead
Back
Arm
Fields
Brake Positions
Power Positions
Brakes
Blow Coil
Spring
Overload Switch
Resistance
Power
Brake
To Trolley

Fig. 79.

90. Auxiliary Fingers.—In the center of the space that the drawing devotes to the power part of the main drum are four fingers R_1, R_3, $D R$, and *34*. These fingers being independent of the main-drum fingers proper and not being in line with them vertically, but being in line with them horizontally, can make contact with one part of a drum tip, while one of the drum fingers proper is resting on another part of the same tip. For example, on the first power notch, main finger B makes contact with tip $B D_1$ at the same time that auxiliary finger $D R$ makes contact with its mate $B D_1$. The object and action of these auxiliary fingers will be taken up later.

91. The Reverse Drums.—The *reverse drum proper*, which is used to reverse the direction of motion of the car, is in the top right-hand corner of the drawing. This reverse drum is the one found on all up-to-date controllers, whether they control electric brakes or not, and interlocks with the main drum in the usual way. On this controller, there are two rows of reverse fingers, each row handling two motors. At the bottom of the controller development, under the main drum, are shown two auxiliary drums, which we will call the *generator reverse drums*, because their object is to keep the armatures of the motors of such polarity that they are connected to generate when the electric-brake connections are in use. The drum on the left is coupled directly to the shaft of the main drum, and so turns in the same direction as and with the main drum; the reverser drum on the right gets its motion through the agency of a gear on the main-drum shaft, and so turns in a direction opposite to that of its mate and the main drum; both of the generator reverse drums, then, are operated by the main drum, without extra precaution on the part of the motorman, and are operated in opposite directions. Each of the generator reverse drums has a neutral position and a row of fingers of its own. Each row of fingers is reproduced on the drawing to facilitate tracing out current paths. Under normal conditions, when the car is going "ahead" and the brake is "off," the fingers *16*, *8*, *17*, *18*, F_4, *20*, on the left-hand drum, and fingers *15*, *14*, *13*, *12*, R_7, *11*, on the right-hand drum, rest on the long strip portions of their respective drums and remain so connected throughout the power positions of the main drum. The current from the trolley passes through the armatures of the car motors in a certain direction.

92. When the motorman throws his power handle to the off-position and continues it in this direction to the first brake notch, the fingers of the two generator reverse drums leave the long strip portions of their drums, pass to the short strip portions, and remain there throughout the six brake positions, thereby so connecting the motor armatures that they can generate.

93. Power Positions.—The power positions are indicated by the row of figures from *1* to *12*. On the first position, fingers T, R_2, *8*, *34*, B, and DR make contact (we will not consider B and DR for the present) on the main drum; all the fingers on the lower drums make contact, excepting *35* and *8*; the reverse switch is "ahead." The current path is through trolley–T–blow coil T_1–finger T–PA_1–PA_1–R_2 through the resistance coil to R_7–R_7–R_7–R_7–R_7 to finger *15* on the right-hand generator reverser–

$$28\left\langle\begin{matrix} A_1-AA_1-12-12-13-F_1-E_1 \\ A_3-AA_3-11-11-11-14-14-F_3-E_3 \end{matrix}\right\rangle E_1-E_1-E_1-34-PC_9-PC_9-PC_2-8-8-8-20-20-20-20-23\left\langle\begin{matrix} A_2-AA_2-17-17-17-17-17-17-18-18-18-F_2-E_2 \\ A_4-AA_4-16-16-16-16-16-F_4-F_4-F_4-F_4-E_4 \end{matrix}\right\rangle G.$$

The current path on the first notch is indicated by the arrowheads. It starts at the trolley; when it gets to reverse finger *28*, it splits, the current dividing between the No. 1 and No. 3 motors; the two currents reunite and flow as one to finger *23*, where they split again through the Nos. 2 and 4 motors, reuniting at E_2 or G, the ground wire. On the second position, the current path is the same except that finger R_4 cuts out two sections of resistance. On the third notch, R_5 cuts out another section, and on the fourth notch the remaining sections are cut out by finger R_7 and T making direct connection through tips PA_4 and PA_1. Upon all the positions just considered, the motors are in series-parallel.

94. Brake Positions.—To operate the brake, the handle is moved backwards from the off-position. To follow the combinations, it is easier to conceive of the main-drum tips moving towards the row of fingers reproduced on the right. It is also simpler to imagine the short tips of the two generator reverse drums to move towards the row of fingers nearest to them, as these two auxiliary drums turn in opposite directions. When the controller drum is moved backwards one notch, all the auxiliary drum fingers engage the tips under the word "brake" and continue to do so throughout the brake positions of the main drum. Main-drum fingers E_1 and G connect through tip BD_1; fingers B and R_1 connect through tips PA_3, BA_4, and BA_1. It will be noticed that finger B is the same distance from tip BA_1 that finger R_1 is from tip PA_3, so that when all the tips move to the right, those two fingers engage their respective tips at the same time. When the generator reverse-drum fingers pass from the long drum tips to the short ones, the armature connections of all the motors are reversed, thereby connecting the motors to act as generators. Consider armatures Nos. 1 and 3; while the long strips on the right-hand drum are in action, R_7 connects through *15* and reverse fingers *28* to A_1 and A_3, while AA_1 and AA_3 connect by way of *12* and *11* to fingers *13* and *14*. When the short strips are in action, A_1 and A_3 connect to *13* and *14* and AA_1, AA_3 to R_7.

95. Starting at finger *15* at the top of the right-hand reverser drum, we will trace a path to ground in both directions. To the right, the path is $15\text{–}\left\langle\begin{matrix}28\text{–}A_1\text{–}AA_1\text{–}12\text{–}12\text{–}R_7\\28\text{–}A_3\text{–}AA_3\text{–}11\text{–}11\text{–}11\text{–}R_7\end{matrix}\right\rangle\text{–}R_7$; $R_7\text{–}R_7\text{–}R_7\text{–}R_7\text{–}R_1\text{–}PA_3\text{–}PA_2\text{–}BA_4\text{–}BA_1\text{–}B\text{–}B_1\text{–}B_2\text{–}B_3\text{–}B_4\text{–}M\text{–}M_1\text{–}M_2$–brakes—to the ground at G. To the left from finger *15*, the path is $15\text{–}\left\langle\begin{matrix}14\text{–}14\text{–}F_3\text{–}E_3\text{–}E_1\text{–}E_1\text{–}E_1\text{–}E_1\text{–}BD_1\text{–}G\\13\text{–}13\text{–}F_1\text{–}E_1\text{–}E_1\text{–}E_1\text{–}E_1\text{–}BD_1\text{–}G\end{matrix}\right\rangle\text{–}G$. The No. 2 and No. 4 motors have one end of their field grounded at E_4 and E_2. Tracing the circuit back, the double path is

$$G-\left\langle\begin{array}{l}E_2-F_2-18-18-18\\E_4-F_4-F_4-F_4-F_4\end{array}\right\rangle-20-20-20-20-\left\langle\begin{array}{l}23-A_2-A\,A_2-\\23-A_4-A\,A_4-\end{array}\right.$$

$$\left.\begin{array}{l}17-17-17-17-17-17\\16-16-16-16-16\end{array}\right\rangle-8-8-8-R_7-R_7-R_7-R_7-R_7-R_1-P\,A_3-P\,A_2-$$

$B\,A_4-B\,A_1-B-B_1-B_2-B_3-B_4-M-M_1-M_2$-brakes-$G$. All four motors have both ends grounded, and are therefore in multiple. No change is made after the first brake notch, except that resistance is cut out successively by fingers R_2, R_4, R_5, and R_7.

96. Fig. 80 is a simple sketch showing the connections of the motors, plugs, blow coil, overload switch, and brakes. The action of the overload switch is as follows: The magnet coil carries the braking current of all the motors; if this current exceeds a certain predecided value, magnet M pulls

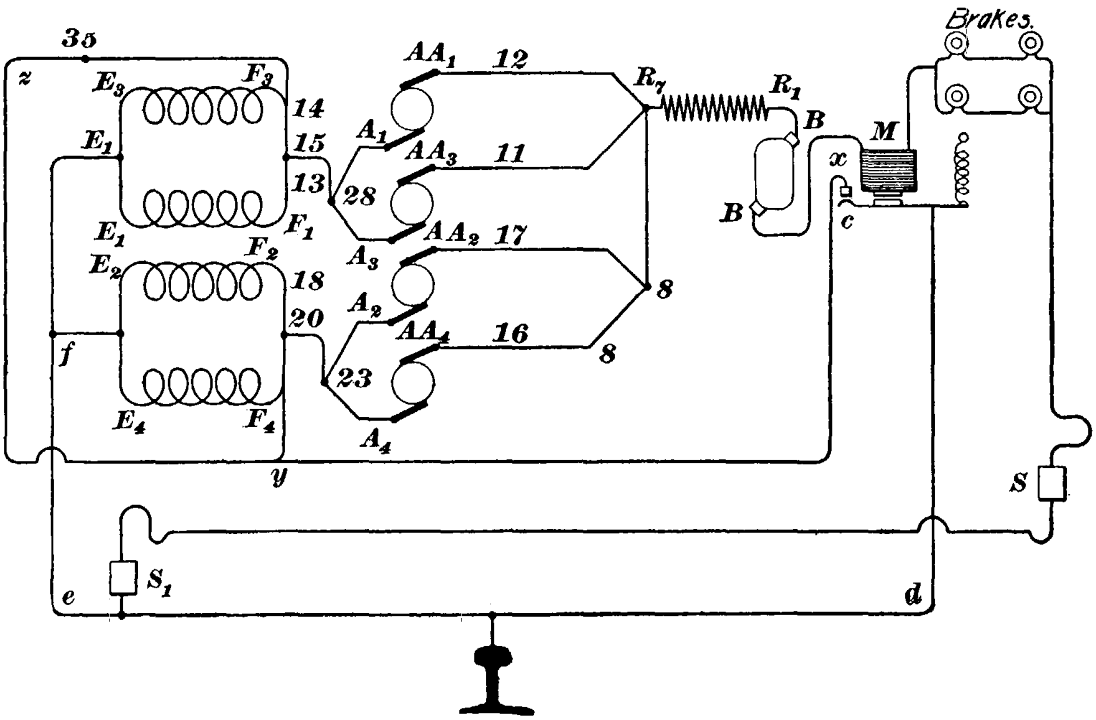


FIG. 80.

on its armature, thereby causing contacts c and x to touch, bringing together wires $x\,y\,z$ and $c\,d\,e\,f$; wire $x\,y\,z$ connects to one end of all the motor fields and wire $c\,d\,e\,f$ to the other end, so that when they touch, the motor fields are all short-circuited, depriving the motors of their ability to generate. As soon as this happens, magnet M releases, opening the short circuit and allowing the fields to build up again.

97. Releasing Brakes.—Full release of the brakes is accomplished by passing a demagnetizing trolley current through the brake coils. This operation is performed through the agency of finger DR and tips BD_1, Fig. 79. The resistance between fingers DR and R_1 is called the *demagnetizing* resistance, because it limits the strength of the demagnetizing current. The resistance is about 60 ohms. The demagnetizing current need be but very small, as the demagnetizing effect is helped considerably by the vibration incidental to the starting of the car. On the first power position, finger B engages one BD_1 tip and finger DR the other, so that on this position current from the trolley wire takes path: trolley–T–T–T_1–T–T–PA_1–PA_1 to finger R_2; here the current splits, part taking the path through the *power* part of the resistance to R_7 and thence to the motors, and part taking the path through the brake part of the resistance to finger DR, thence through path DR–BD_1–BD_1–B–B_1–B_2, etc. to the brakes. This trolley current passes around the brake coils in the opposite direction to what the braking current passed and so destroys the residual magnetism sufficiently to release the brakes.

98. An Exceptional Condition.—In ordinary applications of the brake, it is, of course, only necessary to throw off the power and to continue in that direction to the brake notches, the generator reverse drums tending to the reversal of connections ordinarily accomplished with the reverse switch proper on cars not equipped with electric brakes. In case, however, a car is ascending a hill and the blowing of a fuse causes it to start to roll backwards, the *direction* of *rotation* of the armatures has been reversed, so that their connections need not be; but the act of putting the power handle on a brake notch *has reversed* the connections. With the direction of rotation and armature connections *both* reversed, the motors *cannot* generate. Under such a condition, then, throw the reverse switch proper before putting the controller handle on a brake notch.

WESTINGHOUSE ELECTRIC BRAKE.

99. The Westinghouse electric brake also makes use of the generator action of the motors; but the brake itself differs considerably from the General Electric brake. The Westinghouse brake acts on the regular brake shoes and in addition also operates a pair of shoes that press on the track between the truck wheels. Fig. 81 shows the general arrangement of the brake. *a*, *a'* are the track shoes and *b*, *b'* the regular brake shoes. When not in use, the brake hangs suspended by springs *d*, *d'* a short distance from the rail; *c* is the magnetizing coil supplied with current from the motors running for the time being as generators. When current is sent through *c*, the shoes are pulled down against the track.

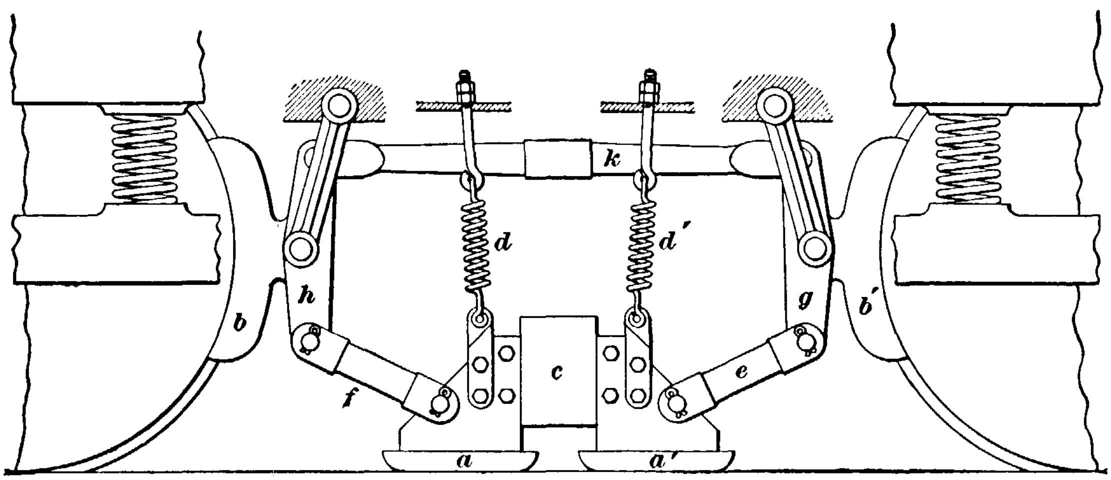


FIG. 81.

At the same time, the drag caused by shoes *a*, *a'* causes the regular brake shoes to be pressed against the wheels through the agency of the levers *e*, *k*, *h*, *f*, thus exerting a powerful braking action.

In the Westinghouse electric-brake system, the connections are arranged so that either the regular car starting resistance or the electric car heaters may be used as the controlling resistance for the brakes. By using the heaters in winter for the brake controlling resistance, a considerable saving is effected, because the current for the heaters is then supplied without drawing on the power station. In other words, heat is used that would otherwise be wasted.

THE MULTIPLE-UNIT SYSTEM.

100. The multiple-unit system is not intended for ordinary street-railway service, but is intended for the operation of trains ordinarily handled by steam engines. A single car with its full equipment for heat, light, brakes, and motive power constitutes a single unit; several such units coupled together into a train, with the proper provision made so that the motors on all the cars can be operated simultaneously from the platform of any car, constitute a multiple-unit train.

101. Suppose we take three ordinary surface trolley cars completely equipped, and that instead of running the car wires from controller to controller on each car and letting them end there, we run the wires from end to end, tapping off to each controller and putting suitable couplers on the ends, as indicated in Fig. 82, so that the car wires on one car can be made continuous with those on the car next to it;

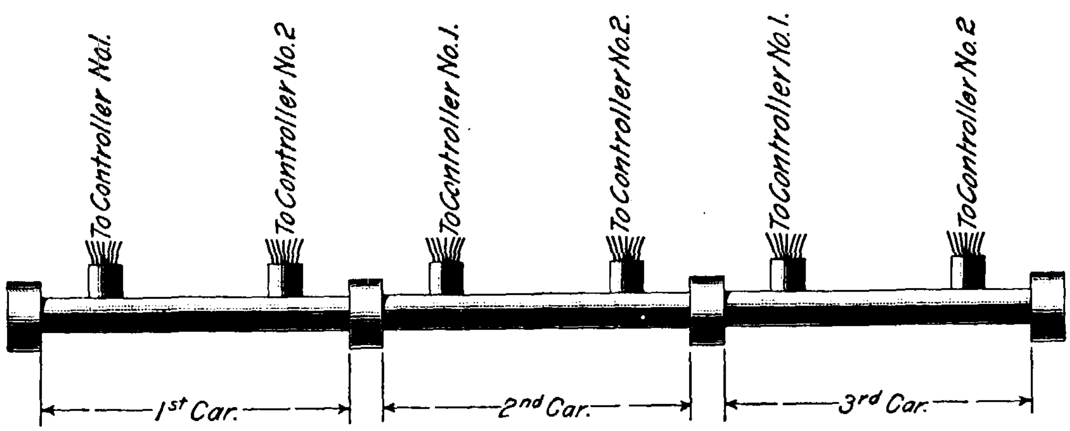


FIG. 82.

then we will have a three-car train. The main-current motor wires will run from one end of the train to the other, irrespective of the length of the train; the train can take the current from one trolley pole or from all the poles at once, and it can be operated from any one controller on any car, whether it is in the middle or on the end. Every car will do its own share of the work, so that the whole train will start, run, and stop as quickly as a single car. This will be a **multiple-unit system**; but there are several strong objections to the adoption of such a system. In the first place, there would be continual trouble with any single controller that would be called on to handle the current of more than two cars. Next, the car wiring would have to be extra heavy, as the wires on the end car, if the train were to be operated from that car, would have to carry the current of all the cars. Again, it would be almost impossible to devise a practicable coupler that would handle such heavy currents without giving continual trouble. Finally, in case of complications arising due to short circuits or grounds on the car wires of any car, the cut-out device that would meet all conditions would have to be very elaborate. These objections have been met and almost entirely overcome by the three multiple-unit systems now on the market. The essential feature of all these systems is that each car is a self-contained unit as far as the main-motor circuit is concerned.

102. On all the systems there is placed upon each platform of every motor car a small controller, called the *master controller*. In no case does this master controller take up over a cubic foot of space. Every car has what is called a train line; the wires running to the master controllers are done up in a small cable provided with couplers on the ends, just as shown in Fig. 82. The wires themselves and the currents that they carry are small, so that none of the troubles incidental to arcing, heating, or burning are encountered. When the train is made up, the train line extends from one end to the other, connecting all the master controllers and the mechanisms that they operate, so that all the main-circuit controllers and hence motors can be operated from any master controller on the train. It must be understood that the master-controller circuit is entirely distinct from the main-motor circuit and is just as free from liability to troubles as an ordinary lamp circuit. The master controller has a series and a multiple position, and it can be seen that it is extremely important that the main-controller operating devices should respond to the notches of the master controller with precision; for if the main-motor controllers should feed up at different rates, a condition might arise where the motors on some cars would be in series and those on other cars in multiple, thus producing a very bad state of affairs. This feature is taken care of by a synchronizing device that not only makes the main-motor controllers notch at the same rate, but also makes the cylinders notch with precision and with a springy centralizing motion that prevents the hanging of an arc.

Every car is provided with an electromagnetic throttle that stops the pilot motor or other device that runs the main-motor controller should the current for any reason exceed a predetermined value, based on the capacity of the motors, the traction of the wheels, and the rate of acceleration desired. The whole equipment is so balanced that the proper acceleration falls within the limit imposed by setting the throttles to work just below the slipping point of the wheels when the car runs light. The throttle makes it practically an impossibility for a motorman to abuse the motors, even should he handle the master controller recklessly. The main controllers can be put under the car, on the platform, under the hood, or inside the car under the seats, if there is room for them.

103. Air Brakes on Multiple-Unit Cars.—Each car has its own air-braking outfit, consisting of a motor-compressor governor, triple valve, tanks, etc., so that if called upon to run alone, it can do so. Simultaneous starting and stopping of the air pumps is accomplished by means of a balance wire running the length of the train and connecting all the junctions of the motor compressors and their governors. Each of the governors is actuated by pressure from the main reservoir, and all these are connected by a balance pipe running the length of the train, so that all compressors are started or stopped by the weakest governor in the lot. The compressor on any car can be cut out, its tank being kept filled by the others. It can be seen that each car is absolutely an independent unit. The advantages of the system in heavy train work are many, and it is destined to fill a large field in the near future. Trains can be split up, shifted, and housed without the aid of any outside source. It also has the advantage that instead of lengthening the intervals between trains in the quiet hours of the day, the time table can be kept the same and the trains themselves shortened, even down to running single cars. Where every car is a motor car, the starts are much smoother, there is no bumping or jerking, as each car starts itself and there is never much tension or compression on the drawbars, and the trains are not apt to break in two.

104. The multiple-unit system has, so far, been used mostly on elevated roads. The outfit is necessarily somewhat complicated, but notwithstanding this fact, it has given good service. The above description will give the student a general idea as to how the system is operated. The details of the different devices and connections are beyond the scope of this Course.