CHAPTER XVI.

ELECTRIC RAILWAY SYSTEMS.

ELECTRIC railway signals have not as yet reached the perfection that steam road devices approach, owing to their more recent application, and the inherent difficulties obtaining in such systems which do not have to be considered in the latter case. Chief among these is the leakage current necessarily the concomitant of a grounded system in which heavy currents at high voltage are employed. This leakage is so great that ordinary battery relays become useless. An advantage, which, however, can be over-estimated, is the power circuit current that can be drawn in any quantity at every point on the right of way. Nearly all signals applied to electric lines employ a contact device operated directly or indirectly by the trolley wheel, third-rail shoe, or other part of the moving car.

On a grounded return direct-current street railway system, or on a steam road which is crossed by or interconnected through ground pipes or bridges with such a system, it sometimes becomes advantageous to use a signaling scheme which will not respond to direct current. The working circuits may be of direct current, this latter either obtained from batteries or the power lines; but the control circuits carry only alternating current. Such an arrangement is represented generically in Fig. 192, the circuits having two insulated components, one containing the secondary, *S*, of a small transformer or converter, and the other the primary coil, *P*. The track is connected to an alternating-current supply, the special laminated magnetic circuit relay, *R*, governing the elements for either a normal clear or a normal danger system. A direct current, whether by leakage or grounded connection, flowing through the primary, cannot induce a current in the secondary or, consequently, operate the signal.

In the New York Subway, but one track is divided into insulated sections, the signals, lamps, and relays being operated by alternating current, these relays having vanes instead of armatures to close the contacts. Several other such systems have been devised and applied, but not to an extent that would warrant their description herein.

On an alternating-current road, the relays can be made of high ohmic impedance, so that an alternating current cannot set up sufficient current in the coils to lift the armature. Direct current is of course used in both supply and control circuits, since the opposing inductance of the relays is but momentary, and manifested only when a change in current strength occurs.

Fig. 193 is a diagram showing the circuit arrangement used in the Uni direct-current system. The trolley wheel, *T*, operates a special switch, *L*, and closes a circuit according to the direction of motion. *I* is a lightning arrester in series with the permanent feed-wire, *M*. The latter is connected to a red lamp, *F*, the locking electromagnet, *A*, the contacts, *E*, operated by *B*, the contact, *D*, lightning arrester *K*, lighting line-wire *R*, and to ground, through similar apparatus at *N*. *B* and *C* are the

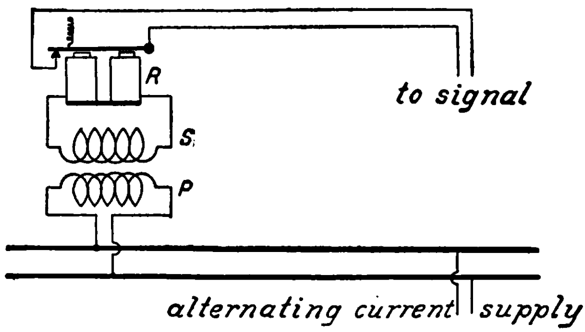

FIG. 192

lighting magnets, since when they are energized the lamps are lighted. These are alternately excited, the cores acting upon a walking beam. In the position shown, the green lamp, *G*, is energized, while in the opposite position, *F* will be in circuit. The extinguishing line-wire, *S*, is in series with *B*, through the lightning arrester, *J*, and the trolley switch, *L*, or the switch contacts, *O*, operated by *C*. *H* is a resistance interposed in the power circuit to keep the current down to the required figure. *A* operates the contacts, *P*, and locks the arrangement, preventing interference.

When a car enters the block, the automatic switch is struck by the trolley, thus lighting the green lamp at the home end of the block, at the same time lighting the red lamp at the distant end; the latter being in series with the former. When the car reaches the trolley switch at the leaving or distant end of the block, both lamps are extinguished. The block is thus unoccupied when both lamps are out, and occupied when either red lamp is in circuit. Since the arrangement is double acting, this applies to cars entering either section. The current carried under any condition is one-half ampere.

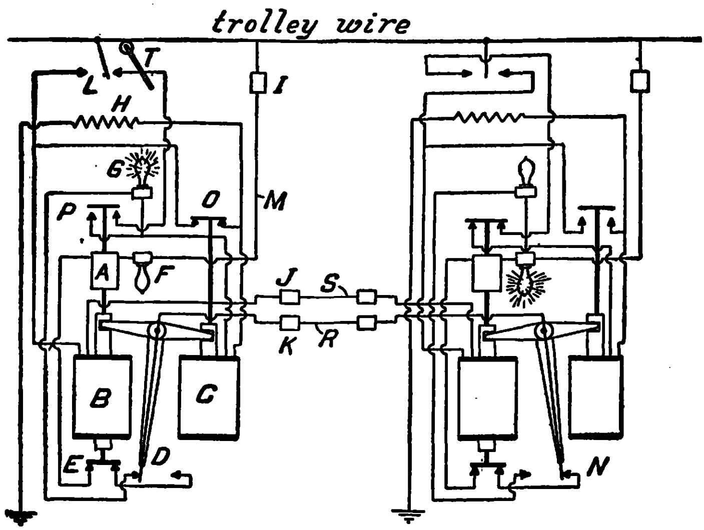

FIG. 193

Unless a car receives a green signal on approaching a block, that block is in a dangerous condition. A car following one already occupying the block does not affect the signal circuits set up by the former, and a visual indication will not be given to either should a lamp burn out. The latter is a remote possibility, since they are renewed monthly.

The single-wire circuit arrangement used in conjunction with the Eureka system, is shown in Fig. 194. *G* is a contact maker, consisting of steel combs having contact teeth, connected on one side to the feed wire and to the rail or ground through the electromagnet, *M*, and the resistance, *R*. The lamps, *L*, are shunted by the resistances, *S*, so that should any burn out the remainder will still give visual indication. *M* operates a contact arrangement consisting of a rotating structure carrying contact fingers *A*, which engage with contacts *P*, *O*, and *N*, according to the position of the mechanism. A similar combination is used at *B*. When, as shown in the figure, the lamps, *L*, are burning, it indicates that the block is occupied. When this does not occur, the lamps are either connected to the feed wire, or to ground only. But one car at a time can thus occupy a block.

In the two-wire system, a diagram of which is given in Fig. 195, a number of cars can be in the block at the same time.

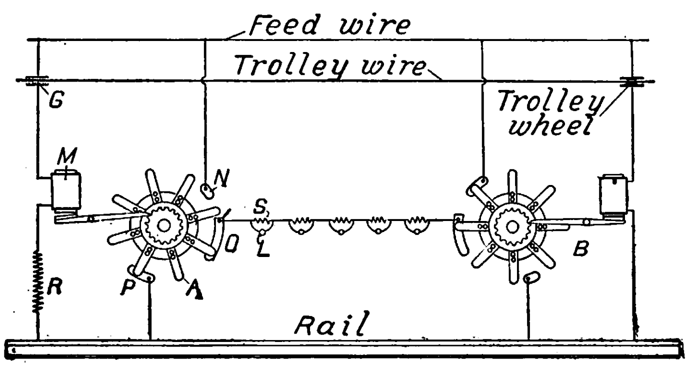

FIG. 194

The contact comb in this case has three members, a long comb on one side of the trolley wire, and two short ones on the opposite side. The main-current controller, *G*, has two electromagnets, *F* and *E*, which act independently upon the rotating member.

When a car enters the block, the current passes from the short comb the wheel comes first in contact with, sending current through the setting magnets and holding the signals at danger. One of the magnets actuates an automatic switch, so that the current passes through the same coil when the second short comb is struck. *C* and *D* constitute a current-directing relay whose function, as above stated, is to keep the current from both short combs flowing through the same magnet, when the trolley wheel strikes the contact maker. When a car enters the block it switches the current from both combs through the operating magnets, setting the system at danger; and when the car leaves the block it similarly sets the system at safety. This occurs in both directions.

Under normal operative conditions, the circuit of an empty block is grounded at both ends. This circuit, as above shown, consists of four green lamps, *g*, in series with a red lamp, *r*, at either end of the block. The controller, *I*, is similar in construction to *G*; the auxiliary controller, *H*, being interposed, whose function it is to open or close the magnet-operating circuit. Should two cars enter the block from opposite ends, this latter opens the circuit automatically, so that one car must back out of the block, thereby restoring the apparatus, and giving the

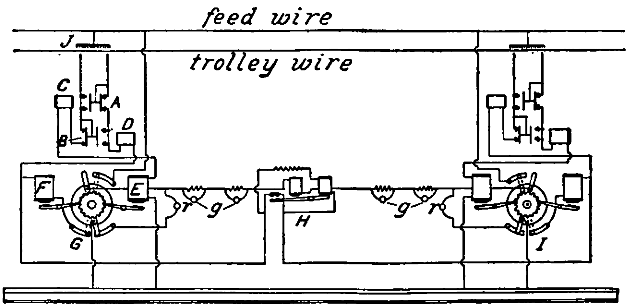

FIG. 195

other car the right of way. When a car enters an unoccupied block, *H* closes the circuit, so that when the car leaves the block at the other end the main controller first energized is again energized, thus restoring the circuits to their normal condition. This device may be dispensed with, but it makes a more effective and desirable combination.

The United States system employs pivoted disks or "semaphores" in addition to lamps, these semaphores being operated by magnets. A mechanical locking device also secures the contacts until released by the car's leaving the block. In Fig. 196, the internal circuits at each end of the block are shown; and in Fig. 197, the external circuits of the entire block. Since but two lamps are normally in circuit at the same time, resistances *R* are interposed to keep down the current. When a car enters the left-hand (or setting) end, the wheel closes the right-hand side of the trolley switch; the current thereby flowing through the magnet, *B*, line 3, to the other signal and ground. When *B* is energized, it throws over its contact lever, thus dis-

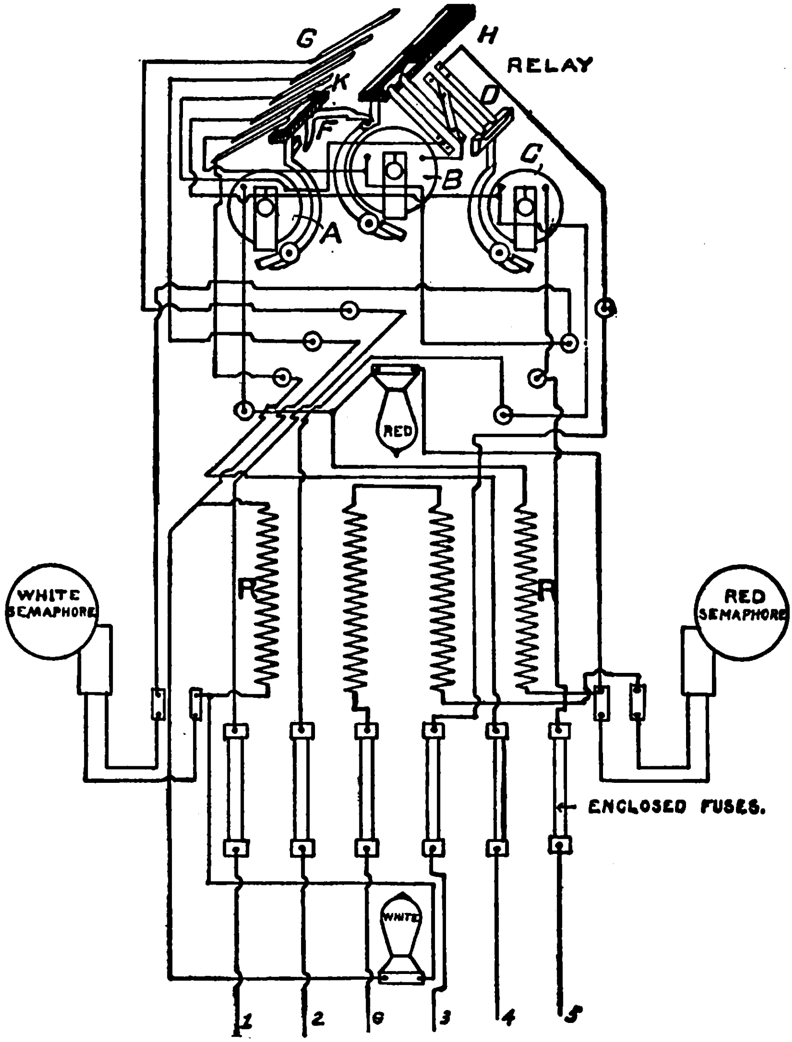

FIG. 196

connecting the ground wire, and putting the feed from the trolley wire into circuit, the trolley switch contact opening immediately after the car has passed. The green lamp is then illuminated and its semaphore thrown, thus indicating that the red lamp and semaphore have been set at the other end of the block. The remaining contacts closed by the movement of the armature of B close a circuit including the outside contact of both trolley switches. The magnet, A, is in series with the signaling circuit, and opens two non-interference contacts in series with the trolley switch, thus preventing a car from entering at the opposite end of the block, locking the lever of the magnet, B, at this end, making a normal indication until the car passes out of this end of the block. Line 2 and its connections constitute a releasing circuit. Upon the car passing out of the block, it operates the outbound trolley switch, closing the right hand

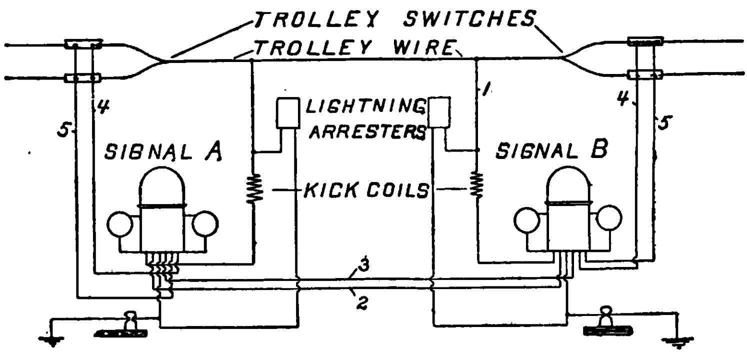

Fig. 197

contacts, sending a current through C at this end of the block, thus breaking the signaling circuits and that of magnet A through the contacts of the latter's armature; and unlocking the armature of B by releasing lock piece F. Since B is deënergized, the apparatus is again in its normal condition. The above sequence of connections occurs with a car moving in either direction. The actual arrangement of the contact carrying members H and K, and of the stationary contacts, G and D, is not as shown in the figure, where an attempt is made only to show the principle.

In the Kinsman system, a remote modification of which is used on the Boston Elevated and Interborough Rapid Transit Railroads (electric, although it is equally well adapted to steam roads), an automatic train-stop is employed in conjunction with a manual or automatic visual system in such a way that the control of the train is taken from the engineman or motorman at a critical time, so that it is not possible to pass a danger signal. This arrangement meets the demand for a device which, independently of the motorman or engineman, would set up a retarding effect, preventing procedure into an occupied or otherwise dangerous block.

Fig. 198 shows the above applied to a normal clear automatic visual system. The home and distant semaphore signal, *S*, has its home control magnet equipped with an auxiliary armature, *m*, which has a front and back contact, and is in series with a switch box, *E*, the slightly elevated guard or contact rails, *G*, and the battery, *B*. These contact rails are each about 120 feet in length, with inwardly curved ends. The battery, *B*, is in two parts; one side having a voltage of about 5, and the other side 3. The front contact of *m* is connected to the junction of these parts, so that when it is in the upper position, the voltage impressed on the circuit will be 3, and in the lower position, 8.

Two contact arms, *K*, are fastened to, and insulated from, the locomotive; these making a scraping contact with the guard rails. Connected to these contact pieces and the engine or car frame is a circuit containing an electrical recording device, *H*, and a stop magnet, *J*, the latter operating directly on the throttle (or control switch, controller, or circuit breaker of an electric train), or being so interposed that it forms a positive link between the throttle and valve. Simultaneously with the shutting off of the steam or current, the air brake is applied.

Returning to Fig. 198, if a train, represented by the locomotive equipment, *H–K*, be moving in an easterly direction with a dangerous track (having the switch *A* open), and consequently with the signal in the danger or stop position; as soon as the contact arms strike the guard rails, a current passes from all of *B* through *m*, to the switch box, guard rails, stop-valve magnet, and returns through the frame of the engine and rail. The stop-valve shuts off the steam, applies the air brake, and, by raising its armature, closes the circuit of the danger-recording magnet, *H*1. This stop-valve magnet requires from 5 to 8 volts at its terminals to operate. At signals *C* and *D*, the same connections obtain. The key switch-box is in series with *m*, so that when the brakeman turns the key, the control circuit will be opened.

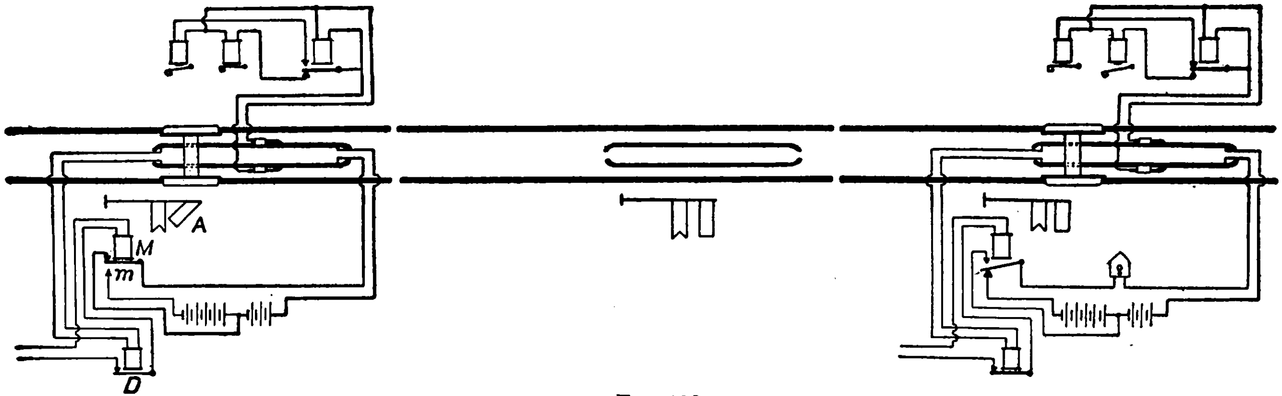

FIG. 198

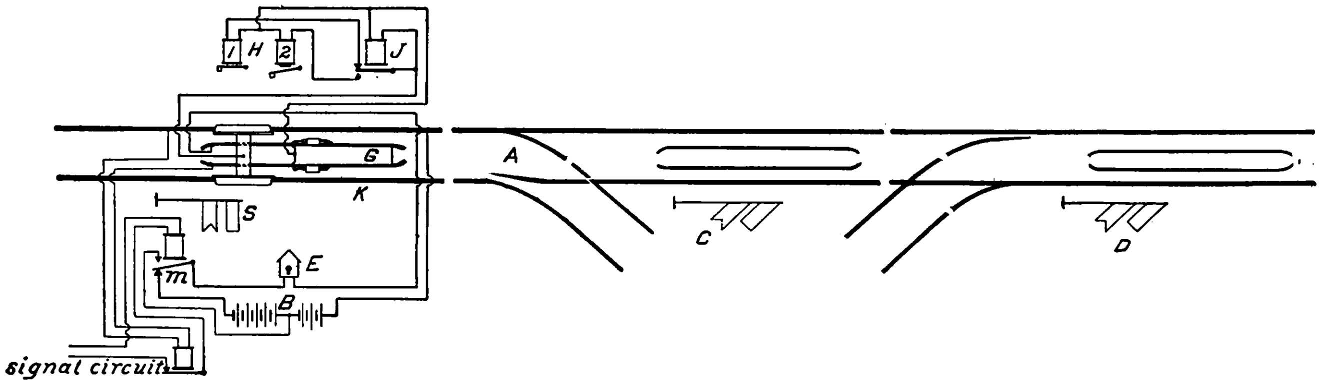

FIG. 199

If the switch at *A* were closed, the visual signal would be in the clear position, hence *m* would close its front contact. This would send a current at a potential of 3 volts through the same circuit, but the stop-valve magnet would not operate. Its armature therefore remains in the lower position, thus causing a current to pass through the safety recording magnet, *H*2.

In Fig. 199 the application to a normal danger system is shown. A train is supposed to be in the distant block of signal *A*, the home block being clear. The current passing through the home magnet, *M*, by way of the armature of the relay, *D*, raises *m* and causes a current to flow through the circuit shown by the heavy lines. Thus the action of the apparatus is similar to that shown in the diagram for normal clear circuits. The current through the recording apparatus is therefore the same in both cases. The latter is not a required part of the arrangement, but its use is advisable, since it serves as a check upon the engineman's statements.

In order that a switching engine may make reverse movements at a signal, the circuit is opened at the switch box, which prevents the signal apparatus from operating. In order to prevent failures in this apparatus from causing disastrous results, a detector circuit is employed, the relay, *D*, being in this circuit, which is normally closed. A broken wire, open or exhausted battery, or other defective condition, will open the circuit at this point, and throw the home signal to the danger position. This will also cause the stop magnet to operate if the train passes the stop signal. If at the same time a failure manifests itself in the locomotive and contact-rail equipments, then disaster may accrue. But the probability of such coincidence events occurring is remote.

The obvious advantages of the Kinsman system are somewhat offset by the necessity of adding parts to a car or locomotive, in opening the circuit at switching movements, the use of contact rails, and the poor protection afforded to a slow-moving freight train pushed by an engine at its rear. An automatic stop, nevertheless, removes one of the greatest disadvantages of visual signaling devices.

A difficulty encountered in a grounded-return system is the disproportionate current carried by the track rails, which is moreover continually varying in value, due to the greater or less conductive continuity outside of the rails, and the uncertainty of the contact of the car wheels therewith. In one system this effect is overcome by making each section a conducting loop with heavy stranded inductive bonds at the insulating joints, which are electrically joined at their adjacent centers. A low-potential transformer secondary with or without an air-gap in the magnetic circuit supplies energy to the section and relays.

Until proper commercial development has occurred it would be out of place to include a description of such devices, however. meritorious they might appear, although several such are being considered by a number of trunk lines.