CHAPTER XVII.

MAINTENANCE.

The operation of cleaning the zinc and removing part of the more or less saturated zinc sulphate solution from a gravity cell is known as patching. Owing to the impurities which occur in commercial zinc, this element becomes coated to a depth of one-half inch or so with an adhesive brown or gray mass, after about two weeks of ordinary continuous operation. This latter must be removed at regular intervals, or it will interfere with the proper circulation of the liquids, and consequently with the operation of the cell. The lower projections of this deposit may either come into direct contact with the copper or with the copper sulphate solution, either of which will produce a partial short-circuit of the cell.

This mass is removed most expeditiously by a dull knife, after which a long-handled brush with short stiff bristles is used to clean the zinc thoroughly. This may be repeated until but a small amount of zinc remains, when a new element must be used. It is never advisable to leave too little or just enough zinc for the last run, as such a proceeding may result in either complete inoperation before the proper time, or, by setting up too weak a current, produce an unreliable movement of the track-relay armature. Although failure of the armature to lift can only hold the signal to which it is connected at the danger position, this entails an unnecessary loss of time to passing trains.

Alternating with the operation of patching is that of renewing. The liquids of the cell are thrown away, excepting about one quart of the zinc sulphate solution, which is retained and furnishes the initial sulphuric acid for the renewed cell. The zinc and copper are cleaned of their deposits, and the undissolved crystals of bluestone saved. Two pounds of new bluestone are added, and after the quart of old solution has been replaced, the cell is filled to the proper height with clean water. Renewing is a wasteful process, but it has not been found practicable to save the saturated copper sulphate solution. The scraps of copper, however, are returned to the supply house. Patching and renewing are performed each month, so that the batteryman goes over his territory every two weeks. This territory, on a double-track road, may be of from 15 to 30 miles in length.

All joints in the wiring of a signal system must be soldered. The best way of accomplishing this is by means of molten solder in a crucible or pot, which is poured over the cleaned and fluxed joint by a ladle. All traces of flux are thus removed, and a thoroughly heated joint with a minimum amount of superfluous solder results. After being soldered, the joint is

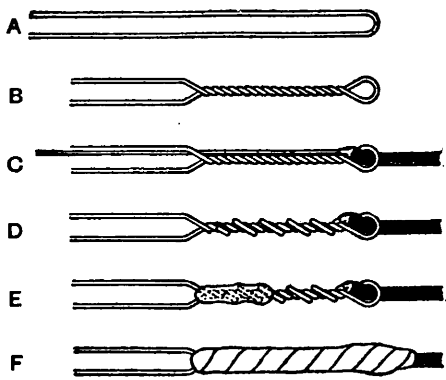

FIG. 200

carefully taped, preferably first with rubber strip, the latter being covered with a thin layer of binding tape. The finishing consists in either gently heating the joint, or painting with a quick drying waterproof solution.

The proper joining of copper conductors to the steel rail is a matter of primary importance, a certain amount of skill being required. In Fig. 200, *A* is the formed iron wire end which is to be connected to the rail by channel pins or plugs, for either a relay, controller, or battery connection. At *B* the wire is twisted, which constitutes the second step, and *C* shows an insulated copper wire inserted in the loop, the insulation being removed from the loop to the end. This wire is twisted around the iron, forming *D*, after which it is soldered, as at *E*, near the end of the joint, so that the insulation will remain uninjured. After making sure that not a trace of flux remains, the joint is taped carefully, as shown at *F*.

The manner of connecting and housing such a taped joint is shown in Fig. 201. *A* gives a section of the rail and an end view of the wood trunking or duct; *B* is a longitudinal section, and *C* an elevation. The weather cap, *D*, is shown removed at *B*.

Track batteries should be frequently and carefully inspected to determine not only their physical condition, but their electrical performance when operating. Faulty or dirty connections may result in the addition of considerable resistance.

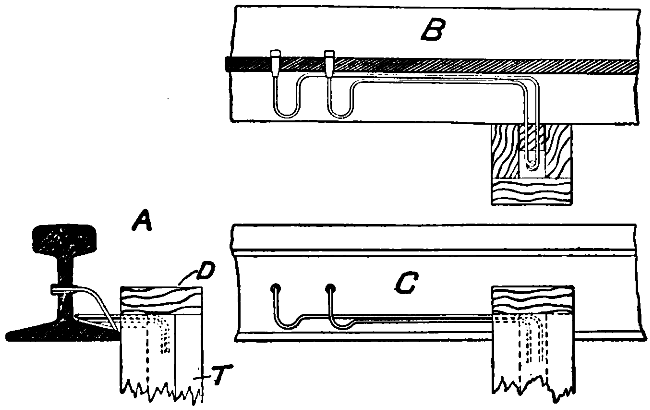

FIG. 201

Thus, in taking a millivoltmeter reading across the cells, and at the track, if even a slight difference occurs, a high resistance may occur between these two points. This may be due to faulty connections, too much or too fine wire, and, in some cases, imperfect contacts at the pole-changing switch.

A relay which fails to close its armature circuit with its minimum current should be at once replaced, and contacts that have been fused by lightning and then separated should be discarded. When track sections are inspected, the bonding, insulating joints, condition of the ballast, rail connections, and line wires should also be given attention. It is well to make memoranda of everything noted, so that local operative conditions may be deduced from the data thus obtained. The numbers of all cut-sections and signals should be tabulated, thus systematizing the entire territory.

When a battery reading is obtained at one end of a section, it should be compared with the reading at the other end of this section. Either may be the battery or relay ends, depending upon the direction taken. Proper drainage of the roadbed must be insisted upon; and the relative amount of moisture present may be found by these readings.

In hot weather the expansion of the rails may force the fiber rail-ends slightly above the level of the rail face. Passing trains then pound off this projecting piece, ultimately destroying the fiber, and sometimes causing the upset parts of the rail to come into contact. This results in one side of the adjacent

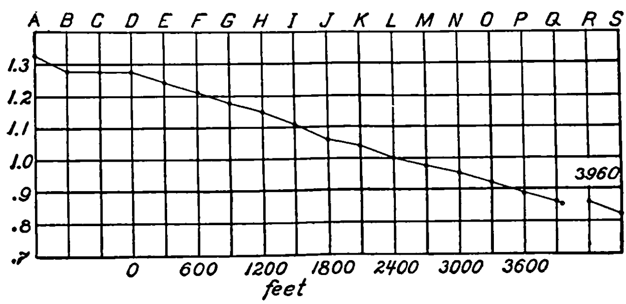

FIG. 202

sections being connected, interfering with the normal operation of the system This is a condition that is difficult to remedy, and replacing of the rail end must ultimately be resorted to.

In Fig. 202 (which shows one square for each one hundred in the original), the voltmeter readings obtained from a typical wireless cut-section have been plotted. The cross-section paper on which the results are given should allow one vertical division for each one-hundredth of a volt, or 100 divisions per volt. Each horizontal division may be equivalent to one rail length, or 30 feet, there being $\frac{5280}{30} = 176$ divisions per mile of track. The voltage curve is found by joining the points of intersection of the voltage reading obtained at each ten-rail section with the horizontal equivalent of the number of rail lengths from the starting point. The voltage is measured at each change in connections. At *A* we have the voltage at the battery terminals; *B* is the voltage at the terminals of the polarity changer; *C* at the connection of the pole-changing switch with the track wires; *D* the voltage between the rails; *E* to *Q*, inclusive, the voltage at the various equidistant divisions; *Q* that at the last rail length considered (No. 132, or 3960 feet from *D*); and *R* and *S* that at the end of the rails and terminals of the track relay respectively. The reason for the line, *D-Q*, not being straight is because of the different effects introduced by the heterogeneous conditions of the ties, unequal depth of ballast, non-uniform resistance of bond wires, and various specific rail resistances; although this curve may be taken as being sufficiently uniform to show good practice. The current taken by the relay (.62 ampere) was too slight to introduce any perceptible temperature effect. With a battery voltage of 1.32 the following readings are apparent from the curve at the various points where measurement was taken.

Voltage at		*Volts*
A, or battery terminals		1.32
B, or pole changer terminals		1.32
C, or track wires		1.32
D, or between rails		1.28
E, or between rails at	10 rail lengths	1.25
F, or between rails at	20 rail lengths	1.21
G, or between rails at	30 rail lengths	1.18
H, or between rails at	40 rail lengths	1.15
I, or between rails at	50 rail lengths	1.10
J, or between rails at	60 rail lengths	1.06
K, or between rails at	70 rail lengths	1.03
L, or between rails at	80 rail lengths	1.00
M, or between rails at	90 rail lengths	.98
N, or between rails at	100 rail lengths	.95
O, or between rails at	110 rail lengths	.92
P, or between rails at	120 rail lengths	.89
Q, or between rails at	130 rail lengths	.86
R, or pole changer at	132 rail lengths	.84
S, or track relay at	132 rail lengths	.82

Should abrupt changes occur in the direction of such a curve, it indicates that conditions at this point are abnormal. Thus, a high-resistance bond wire, or poor joints in a series of rail lengths will result in a line which does not conform to the general direction of the remainder of the line. Theoretically, the line joining the points at which indications are taken should be straight, but the factors above mentioned introduce variations of direction. Should considerable current leakage occur, the change in the direction of the line would be at once evident. The curve given is a fair example of what may be expected with gravel ballast, with a relay of 3 1-2 ohms resistance, which requires a minimum of .23 volts to lift its armature. This condition gives a wide possible variation of voltage through which the armature will rise, which is necessary, because of variations in the weather conditions. On account of the decrease in the length of air-gap, and the consequent increase in the permeability caused by the motion of an armature, it follows that the minimum voltages that commence motion will produce a good closing of the contacts.

The voltage of the relay being .82 and its resistance 3.5 ohms, the current flowing through it will be .82 ÷ 3.5 or .234 ampere. As the output of the battery is .62 ampere, the relay evidently takes only a fraction of the total current, or 38 per cent; the remainder, 62 per cent, being shunted across the rails by the ballast and timbers, which represents an average percentage of leakage, the drops in potential in the rail being also considered.

Where cinders or culm are intermixed with gravel, or when the former are used exclusively as ballast, a material change in the readings obtained will be evident. This is due to the better conducting qualities of the former and to the better contact usually made with the rail. Fig. 203 illustrates an average of such cases. A battery of six gravity cells, connected in multiple, was used in this case, the current passing to the rails being one ampere, *A* being the voltage at the battery and *B* at the track. From *B* to *M* are measurements taken at regular intervals of 600 feet (20 rail lengths), the section being 7020 feet in length, *N* being the track voltage at the end of the section, and .35 the voltage at the relay.

The relay resistance is 3.5 ohms, with a terminal e.m.f. of .35 volts, the current taken being .35 ÷ 3.5 or .1 ampere, the remaining .9 ampere or 90 per cent leakage through the ballast from rail to rail.

This represents a case where failure of the relay to operate may be expected in wet weather, owing to the better conducting qualities of the ballast at such times. Since .35 volt is just above the operating e.m.f. or such a relay, the reason for such failure is obvious.

The conditions above represented may be eliminated by shortening the length of the section, or by dividing it into a number of sections. If we divide it into two equal parts, and use two sets of batteries and relays, the length of each section will be 3510 feet, the e.m.f. at the end of the first section will be (from the curve) about .51 volt, or 46 per cent above .35 volt.

Since a greater relative gain is made by excluding some of the loss due to the track leakage, the actual result will be some-

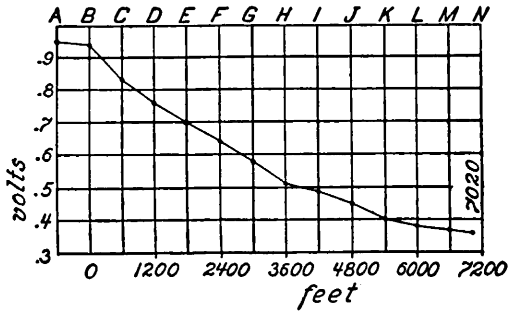

FIG. 203

what in excess to the above. It should be remembered that a track section must be designed to give a maximum of voltage at the relay, with a minimum of leakage, so that a minimum number of track cells in multiple is required. Because of the great variations in the resistance and insulation of a track section, it is not possible to give a fixed rule as to the voltage that should be maintained at the terminals of a relay.

Numerous multiple paths are afforded, even under favorable conditions, for leakage from rail to rail. For this reason the voltage across the latter must be very low, otherwise the percentage of lost energy will be too high. This voltage, however, could not be excessively low (as for instance that which would be obtained from a few thermoelectric couples in series) or relays could not be satisfactorily operated, and the shunting action of a train in a long section might not remove sufficient current from such a relay's coils. Ties are of hard wood of high specific resistance, but since from ten to twenty-five thousand spikes are driven in them to the mile, it is seen that the reduction in insulation resistance becomes very great indeed. Particularly is this true when the ties are wet and slate or culm ballast is used. The latter frequently contains considerable sulphuric acid, which, by associating with the water, greatly reduces the specific resistance of the ballast.

With properly designed relays and other current-taking devices a larger number of cells should preferably be used in the main battery than is required under normal conditions. This is because the cells ordinarily used are more efficient when a moderate current is taken from them. Abnormal current discharge results in polarization (with concomitant increase of resistance, loss of energy, and reverse e.m.f.), sluggishness of chemical action, and poor recuperation, while the ampere-hour capacity is greatly reduced.

In winter, cells have to withstand long-continued low temperature, which decreases their terminal voltage somewhat, and increases their terminal resistance. The drop in potential in a battery is thus much greater when low temperatures obtain, so that the load upon them is increased, especially when motors are in circuit. Motors require heavy initial current discharge, so that the voltage falls very rapidly when they are in circuit. High voltage thus becomes desirable in a signal circuit, and is more than compensated for in economy of operation. Another argument for high voltage is the liability of a low potential not overcoming the resistance under the motor brushes which a particle of dirt, congealed lubricant, or moisture interposes.

To find the insulation resistance of any circuit, as, for instance, that between the rails of a track section, having given a voltmeter whose resistance is known, connect the latter in series with the resistance to be measured, and a battery whose voltage is approximately equal to the range of the voltmeter scale. After noting the reading, measure the battery voltage. Divide this latter result by the former, and add one to the quotient, which, when multiplied by the voltmeter resistance gives the required resistance. Thus with a battery reading of 2.8 volts, and a resistance reading of .9 volt with a voltmeter resistance of 200 ohms, the unknown resistance will be $\left(\frac{2.8}{.9}+1\right) \times 200 = 822$ ohms.

The slot and slow-releasing magnets of a normal clear two-arm semaphore signal, with a working battery of 16 cells (11.2 volts) require a current of 16 milliamperes (.016 ampere). These three magnets, which are connected in multiple with the battery, have a combined resistance of 700 ohms, and have sometimes equal resistances, or about 2100 ohms each. The total current required per day (assuming that the semaphores remain at clear) is, therefore, .384 ampere-hour. The average motor current required is two amperes, the actual current being greater when the motor starts, and less when full speed is reached, due to the full counter e.m.f. which is developed in the latter case.

With 100 train movements a day, both semaphores would operate 100 times, so that the motor actually operates 200 times. With trains in the block for say three minutes each, the slot magnets would not be energized for 300 minutes out of each day, or 5 hours. The daily current discharge into the slot and slow-releasing magnets is thus only .304 ampere-hour. There can be eight blade movements per minute of motor operation, so that the motor will be in use for 25 minutes a day, or .416 hour, the current required being .932 ampere-hour, which, added to the .304 ampere-hours required for the slots, etc., gives 1.236 ampere-hours. As the capacity of the cells used is ordinarily 300 ampere-hours, they will last when operating this signal for about 240 days, allowing for some depreciation.

When a smaller number of train movements occur the cells will last longer. One-arm signals could be relied on to give a battery life of from one to two years, the latter being in extreme cases, as the best of cells cannot be left on an intermittent circuit for so long a time and be depended upon. The resistances of the compound slot magnets of a signal can have high values, owing to the heavy series winding which carries the motor current when the latter is operating, and thus compensate for the drop in potential due to the momentary heavy demand on the battery.

Maintainers and inspectors will find a voltmeter having two scales desirable: one reading up to three volts, and having fifty divisions per volt; and the other reading up to 15 volts with ten divisions per volt. With the former it is possible to read, with some show of accuracy, in millivolts. A milliammeter is also a useful prerequisite to check up the resistances and input of relays and other magnets.

Motor brushes should be adjusted to exert only such pressure upon the commutator as is consistant with good electrical contact. The ends or leaves should be spread apart, to avoid the introduction of an open circuit by contact only with one of the mica strips separating the bars.

The buffers or dashpots on motor signals should receive careful attention, otherwise injury will result to the moving system or too great a retardation will occur. The vent should be so adjusted that the loss of speed (resulting on the tendency to form a vacuum) when clearing is imperceptible. In lubricating, heavy oil must not be used and care should be taken that dust or dirt does not enter the buffer chamber. A light non-freezing oil is best for use on all moving parts, including the motor commutator, it being sparingly applied on the latter by a cloth. When a signal is in the danger position all the weight of the moving system should be borne by the spectacle casting and its stop. On no account should the slot be impeded in any way.

The clearing of a semaphore by a motor is a rather tedious process, from six seconds to a quarter of a minute being required. With a two-arm arrangement, the motor must start up twice when the distant and home are cleared in the proper sequence after a train has passed a signal.

Relay boxes must be of such construction that insects cannot enter, as their operation sometimes causes open circuits or false conditions. They must also be weatherproof, although extreme care need not be exercised, providing the relays are enclosed in glass covers, which is the present practice in construction. Motor armatures should also be well protected, particularly at the commutator end, as a trifling amount of dirt at this part may cause endless trouble. Although an open circuit in the motor can only result in a false danger indication, this produces a certain amount of delay to through trains. All operated contacts must be enclosed in closed housings to prevent access of moisture or dust.

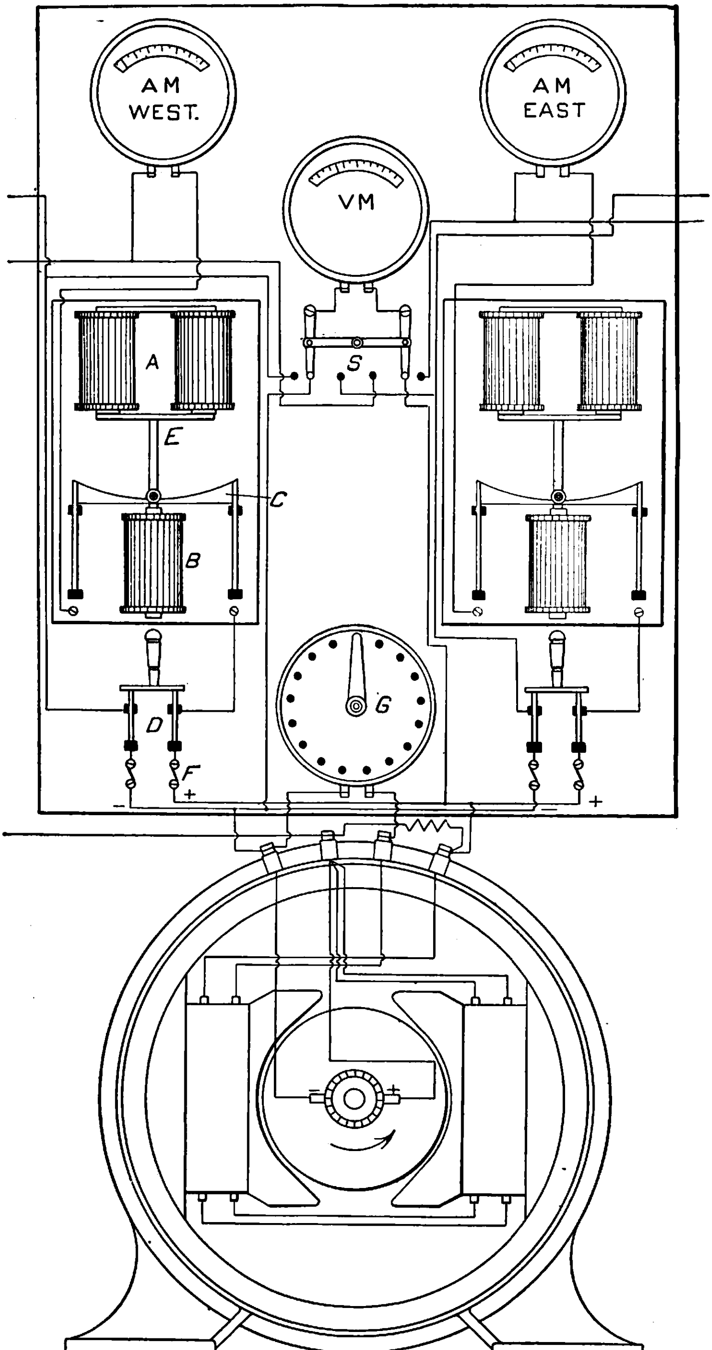

FIG. 204

Engineers or conductors are generally requested to fill out blanks when held by a signal for which the immediate cause is unknown. These are passed to the maintainer or inspector, whose duty is to at once examine the signals and accessories to determine the cause of failure. Maintainers, batterymen, supervisors, and engineers, with the maintenance-of-way corps, exercise such a strict observance of the working conditions that it is not often a failure takes place undetected. Such constant supervision, particularly on roads having heavy traffic, is absolutely necessary to keep up the integrity of a signal system.

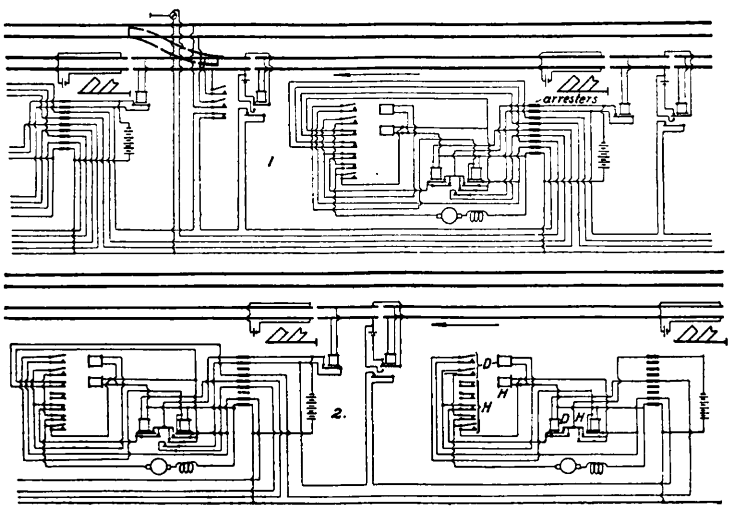

FIG. 205

When any serious trouble occurs, its results increase with great rapidity, owing to the momentous position which signals possess in a competent aggrandization. Maintainers must go over their entire territory immediately subsequent to a lightning storm, replacing fuses and inspecting relay points. Special engines are delegated to assist in performing this service, a flurry of telegrams and messages being coincident.

Continuous spectacles and castings are advancing in favor, and are meritorious because they prevent a clear indication until the semaphore has described more than two-thirds of its working arc, also eliminating the complete shutting off of the

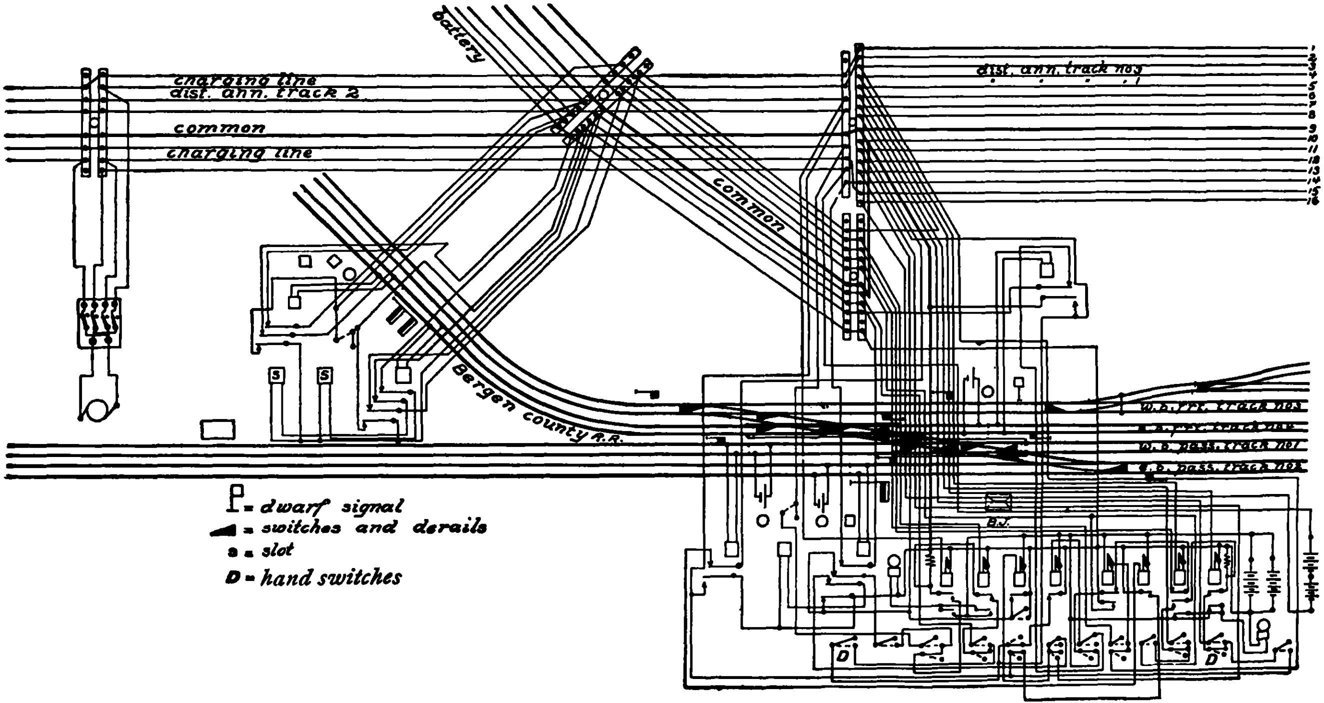
charging line
dist. ann. track 2
common
charging line
battery
common
Bergen county R.R.
B.J.
= dwarf signal
= switches and derails
s = slot
D = hand switches

FIG. 206

light at any point or angle of transition when moving for an indication. A drooping semaphore may readily be detected in

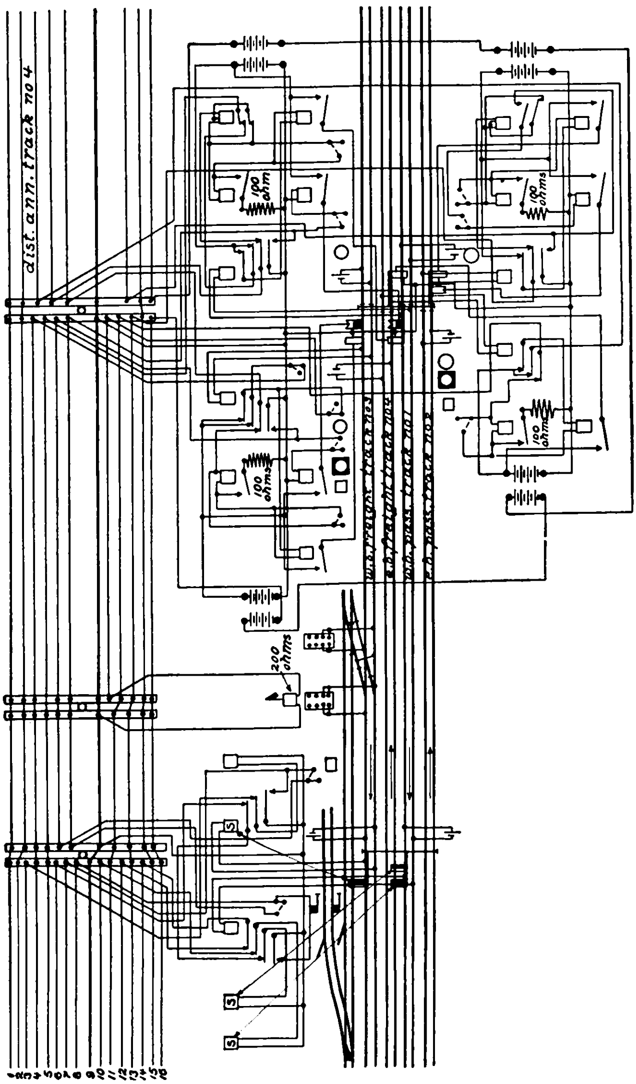

FIG. 207

daylight by the engineman; but in the dark this is difficult, as he is only governed by the color of the intercepted light. Hence, a partly cleared or improperly displayed member, while readily perceived in the daytime, at night may give a clear indication when such is wrong. Sight shields only remedy this difficulty, by showing the engineman that he must come to a stop, by reason of the rules governing improperly displayed signals.

Fig. 204 shows a generator and switchboard used in a typical transmission scheme for storage battery charging. The generator has a terminal e.m.f. of 500 volts, and in this case is bipolar and compounded. The series winding is shunted for adjustment of the compounding, an equalizer being used when two or more are connected in multiple. The switchboard contains, on each side, a main switch, *D*, circuit-breaker *E*, fuses *F*, ammeter *A M*, and a voltmeter, *V M*, which is thrown on either side of the lines by switch *S*. The circuit-breaker will open on "no voltage" or "reverse current," by the action of the shunt coil, *A*, or through an overload by the series coil, *B*, the contact blades being shown at *C*. *G* is a rheostat for changing the terminal voltage by variation in the current passing through the shunt field-coils. The individual storage batteries, both east and west, are connected in series. The use of two multiple lines assures the maximum distance of transmission at a minimum line loss.

We have, in Fig. 205, a comprehensive, normal, clear circuit, such as occurs on the L. S. and M. S. R. R., which includes most of the connections that have heretofore been considered. In view of the preceding descriptions, this need not be analyzed, but it covers the standard storage battery-line wire arrangement now being extensively applied to trunk lines.

In conclusion, Figs. 206 and 207 contemplate normal danger circuits on the Erie Railroad, from Bergen, N. J., to Suffern, N. Y. Included therein are slot control of mechanical semaphores, a charging line arrangement, and indicators at *B J*, tower. This exemplifies the circuits usually employed at interlocking plants, and is typical of the electrical control of long-established mechanically operated semaphores, and their application as a supplement to an automatic network.