New Automatic Signals on Grand Trunk

Local Conditions Prompted the Adoption of an A. C. System on 19-Mile Section Near Chicago

By B. Wheelwright,
Assistant Signal Engineer

A Double Signal Location.

The Grand Trunk has recently placed in service a new double-track signal installation between Thornton Junction, Ill., and C. & W. I. Junction, within the city limits of Chicago. The latter point is the end of this company's line, as its trains use the tracks of the Chicago & Western Indiana from there to the Dearborn street station. This 20 mile installation completes the automatic signal protection on the double-track main line of the Grand Trunk from Chicago to Granger, Mich., approximately 108 miles. At Thornton Junction the new a. c. signal installation ties into the d. c. installation placed in service late in 1912.

TRAFFIC AND LOCAL CONDITIONS

The traffic between Thornton Junction and Chicago is very heavy, for in addition to the regular main-line business, the Chicago suburban traffic and all of the Chicago freight transfer work have to be handled. This leads to a comparatively short length of block, the average being slightly less than a mile.

When the plans for this installation were made, it was felt that this short block length and the use of a. c. track circuits would obviate the necessity for repeating track cuts and the work was so installed. However, satisfactory operation could not be obtained during the warm summer rains, and it was found necessary to cut 12 of the track sections, and in one case, to reduce the length of the section to approximately 1,800 ft. before satisfactory operation under all weather conditions could be obtained.

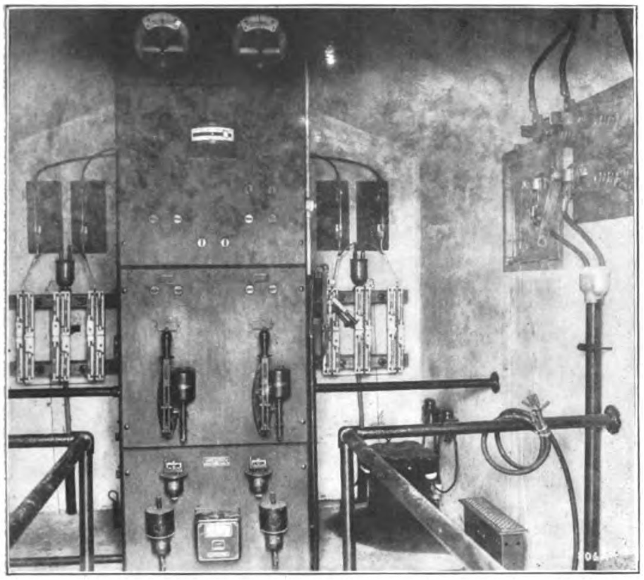
The track conditions on this installation were unusually severe, and it is probable that certain of these blocks could not have been operated satisfactorily with d. c. track circuits. The most of the trouble was experienced on the eastbound track. For many years, the Grand Trunk has had a heavy east-bound refrigerator-car traffic, and the brine dripping from these cars has thoroughly impregnated the ballast and even new ties. The thoroughness of this brine impregnation is shown by the fact that the ballast in drying out after a warm shower will be almost white with salt crystallizing on the surface. For most of the first ten miles out of Chicago the line traverses a flat, swampy country, where the ground water level is very close to the surface. Through capillary attraction much of the ballast is kept constantly moist, and this, of course, aggravates the trouble.

The calculated ballast resistance for portions of the east-bound track during the very wet summer weather is about 0.3 ohm per thousand feet of track. This same ballast, when dry, has a calculated ballast resistance of 5 to 6 ohms per thousand feet, which shows it to be average ballast for track circuit work when dry. The change in ballast resistance takes place very rapidly during warm summer rains, ten minutes often being sufficient for it to drop to 0.6 ohm per thousand feet. The temperature has a very marked effect on this action; that is, a cold rain will not reduce the ballast resistance to anywhere near the point that the same amount of precipitation will if the temperature is higher. The only explanation of this fact seems to be that the solubility of the salt increases with the temperature, thus giving a path of lower resistance for the leakage current due to the increased amount of salt dissolved in the water. A steady light rain appears to reduce the ballast resistance more than a heavy rain, probably due to the fact that the latter washes much of the salt away, while the former allows it to more thoroughly impregnate the ties and ballast.

A further harmful effect of these brine drippings is that a coating of rust scale has been formed on the rail and angle bars. This scale is a good insulator and as a result forces practically all of the track current to flow through the bond wires, instead of a considerable portion flowing through the angle bars and the abutting rail ends. This materially increases the total rail resistance and impedance. A recent test on rail similarly coated in d. c. territory clearly shows this point. In opposite track sections of the same length and ballast conditions on double-track, the rail on the east-bound track was rust coated, while the west-bound rail was practically free from scale. A variable resistance in the battery circuit was adjusted so as to produce the same potential across the rails at the battery end of each section. Approximately the same current was flowing through each track relay. The bond wires around one joint at the battery end of each section were then cut. In the case of the east-bound track, this reduced the current through the relay 40 per cent, while on the west-bound track, the current was only reduced

11 per cent. The result of this test led to the adoption on the east-bound track of three copper-clad bond wires at each joint instead of two iron wires. This remedied certain sections, but where conditions were very bad and the length was over 3,000 ft., the section had to be shortened to secure satisfactory service.

In addition to the track circuit conditions, described above, the availability of a. c. commercial power at reasonable rates and the possibility of handling the lighting of signals



Interior of Elsdon Substation.

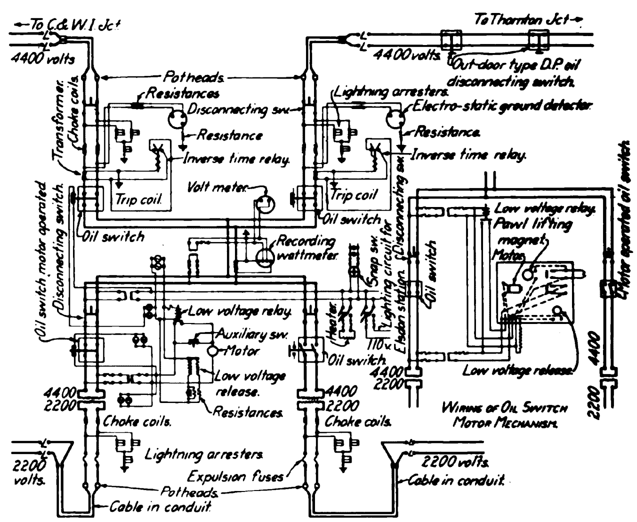
and buildings from the transmission line were important considerations in the decision to install the a. c. system. The lighting feature has proved most successful, as shown by the fact that the lighting load is approximately twice the signal load. Power is purchased under a wholesale contract at a cost which amounts to approximately three cents per kw. h., and will be even less as the load increases. Previously the lighting load was metered at a great many points and purchased at retail lighting prices at an average cost of about eight cents per kw. h. This saving, capitalized, would go a long way toward paying the first cost of the transmission line. A further advantage is that this cheap lighting enables the road to light electrically even its smallest stations within this zone, thus giving better service to the patrons of the road at a cost that is practically the same as for oil lighting.

POWER SUPPLY AND TRANSMISSION

In view of the numerous lines in this territory from which power could be obtained, it did not seem advisable for the company to attempt to generate its own current. A short distance each side of Elsdon, which is the center for the combined signal and lighting load, two independent 2,200-volt distributing circuits of the Commonwealth Edison Company cross the right of way, from which single-phase, 60-cycle power is carried to a substation at Elsdon.

The substation equipment is housed in a portable 9-ft. by 13-ft. reinforced concrete building, which was poured *en bloc*, all the conduit and wiring being concealed in the concrete. Window frames and windows are made of sheet steel, arranged to be let down from the inside. Electric lights are provided, so that ordinarily no daylight illumination is required. The door and door frames are also of sheet steel. The steel windows and door were decided upon to prevent damage by boys or rowdies, who at times cause considerable trouble in this vicinity.

Power is normally taken from one source only, and the other is held as reserve. Automatic, motor-operated oil switches are so arranged that if power fails on the normal or regular source for more than 30 seconds, the oil switch on this circuit automatically opens, and the oil switch on the reserve source is automatically closed. This apparatus operates as follows: A single-phase repulsion motor drives a small worm gear when the low-voltage relay, which is connected across the signal feeder line, has made contact; in other words, when the voltage on the feeder circuit has failed. Each revolution of the worm gear advances a ratchet one tooth, by means of a pawl. One revolution of the worm gear requires two seconds. The ratchet has 15 teeth, so that 30 seconds are required for a complete movement. The number of teeth which can be engaged by the pawl is adjustable, so that any desired time from 2 to 30 seconds can be had. The movement of the ratchet on the last tooth drives a lever which connects to the oil-switch lever through a hook. If the feeder circuit is alive, a magnet lifts the hook so that the oil switch remains open when the ratchet operates the lever and the mechanism completes its cycle of operation without having closed the switch. After the ratchet has completed its travel, it automatically returns to the starting position. This position may, as previously explained, be adjusted so that any number of teeth from 1 to 15 must be operated by the pawl before the oil switch is closed. The first movement of the ratchet closes an auxiliary switch, which remains closed and keeps the motor running until the ratchet has completed its travel and returned to the starting position regardless of whether it closes the oil switch. This removes from the relay contacts the circuit which otherwise would have to be broken by them. The oil switch is held closed by a low-voltage magnet, which will release the switch when the voltage falls below one-half of normal. The following action takes place in case both sources of power fail and become alive again at the same time. One mechanism is set at 20 seconds and the other at 30 seconds. Both mechanisms begin to operate. The 20-second mechanism, of course, closes its oil switch first and also



Wiring Plan of Substation Apparatus

energizes the magnets which control the hooks on the other mechanism.

The circuits in the substation are shown in one of the accompanying drawings. The outgoing signal transmission circuits lead from the main 4,400-volt bus, being controlled through hand-operated oil switches equipped with overload release. This allows separate control for the lines east and west of the substation. Each outgoing circuit is equipped with an electro-static ground detector; there is a voltmeter on the switchboard to measure the potential fed to the transmission lines and also an integrating watt-hour meter showing the total amount of power taken by these lines.

General Electric Company station type multigap shunt lightning arresters are installed in the substation and similar line type arresters on the pole at the line end of the lead-covered cables, in which the 2,200-volt feeder circuits and the 4,400-volt transmission lines are enclosed. Disconnecting switches are installed so all the apparatus can be tested or repaired without cutting permanent connections. A complete system of pilot lights on the switchboard shows when the various circuits are alive.

It was felt sufficient heat would be generated in the power transformers to heat the substation building, but for unusually cold weather an auxiliary 800-watt, portable electric heater was installed.

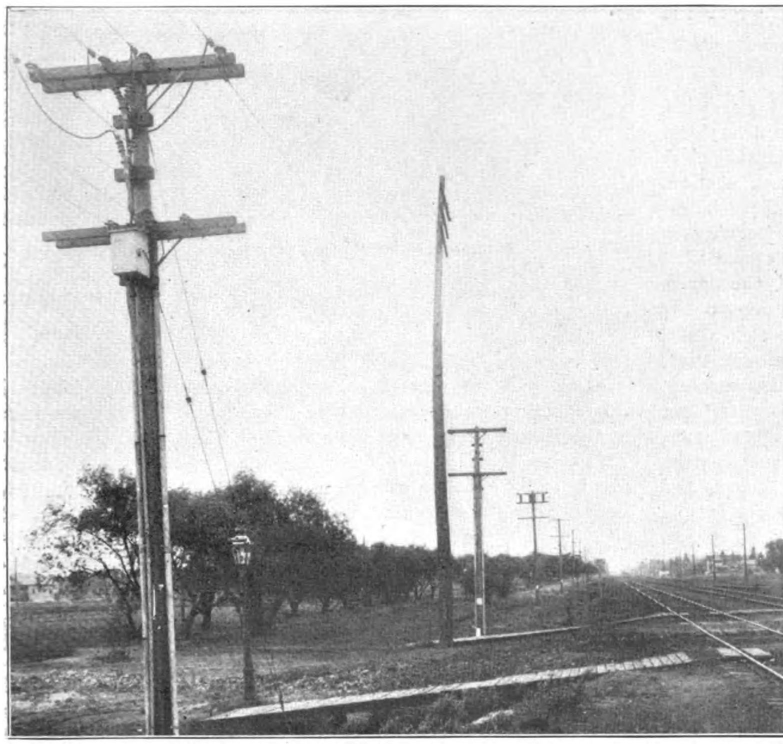
A steel-core, stranded aluminum cable of a resistance approximately equivalent to that of a No. 6 B. & S. gage, hard-drawn copper wire is used for the high-tension transmission line. The reasons that led to the use of aluminum instead of copper were: First, greater mechanical strength together with less weight; second, its ability to withstand rougher treatment without serious damage, and, third, a small saving in first cost. Within the city limits of Chicago municipal regulations required a weatherproof triple braid insulation on this line, but throughout the rest of the installation bare cable was used. No. 10 B. & S. gage, 40 per cent bare copper-clad line wire is used for the low-tension line. A clearance of 6 ft. is maintained between the high and low tension lines.

For the high-tension line, double petticoat porcelain insulators are used, designed for 7,500 volts working pressure, thus insuring an ample factor of safety for line insulation. Galvanized steel insulator pins with wood cobs and Belden galvanized steel cross-arm gains are used throughout. All dead ends in both the high and low tension lines are made on special strain insulators in order to do away with the vertical plane bending stress in the cross-arms and to provide greater security than is possible with pin insulators. The pole line is carefully graded, the average length of pole in open country being about 30 ft. Poles are of first-quality cedar, the tops and butts being treated with one coat of carbolineum.

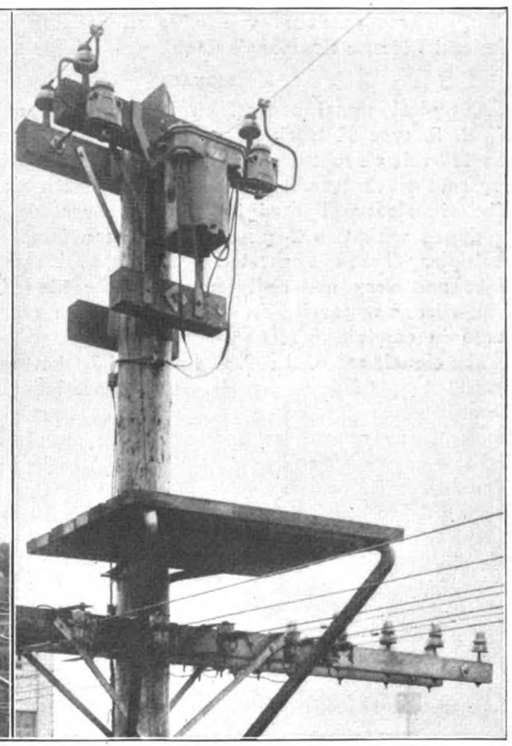
The transmission line at many points crosses heavy telephone trunk lines and other congested wire lines. In these cases it was necessary either to go over these wire lines with a minimum clearance of 2 ft. for the lowest wire (8 ft. for high-tension wires), or to resort to underground cable construction. The former method was employed in those cases where the necessary clearance could be obtained by using a 55-ft. pole, but where poles higher than this were required, underground construction was used. It was felt that the difficulty in properly grading these extremely high poles and safely guying them against sleet storms justified the increased cost of underground cable construction. Further, a few excessively high poles, such as these, would tend to draw lightning discharges to the line. There are nine of these underground cable crossings, aggregating about 2,200 ft. of cable. A duplex No. 6 B. & S. gage, flexible copper cable, insulated with varnished cambric and tape and protected with 3-32-in. lead sheath, is used. The cable insulation was designed to withstand 9,000 volts working pressure, so as to insure an ample factor of safety. The cable is carried without joint or break from pole to pole and is enclosed in 3-in. galvanized iron conduit. This conduit is carried up the pole to a point above the low-tension crossarm, so as to thoroughly protect the cable from injury. Davis open-air cable terminals, designed for 7,500 volts working pressure, are used to connect the cable to the transmission line. This cable terminal allows of easy disconnection in case of cable trouble or testing. These terminals are attached to the cable by means of a wiped joint, thus preventing as far as possible all chance of moisture getting into the cable.

A multi-conductor, No. 10 B. & S. gage, flexible copper cable, insulated with rubber and tape and protected with 3-32-in. lead sheath, is used for the underground low-tension circuits. The insulation was designed to withstand 600 volts working pressure. The cable is enclosed in galvanized iron conduit, which is carried up into the low-tension cable terminal box on the pole.

The high-tension line is equipped with General Electric Company single-pole multigap graded shunt lightning ar-



Connections from Underground Cable to Pole Line.



Transformer Location on Pole.

resters at each end of all underground cable runs, and at each transformer location except where two or more occur within one mile, in which case only one set of arresters is installed. No. 2 Paragon ground cones set in coke are used for the grounds. Porcelain transformer fuse cutout plugs are installed between line and arrester, so the latter can be disconnected for cleaning or repairs. G. R. S. type 1A lightning aresters are used on all low-tension line and track connections. Grounds for these are made by coiling 20 ft. of No. 6 B. & S. gage bare copper wire and placing it 6 in. below the concrete signal or relay post foundation. In no case are high and low tension lightning arresters connected to the same ground.

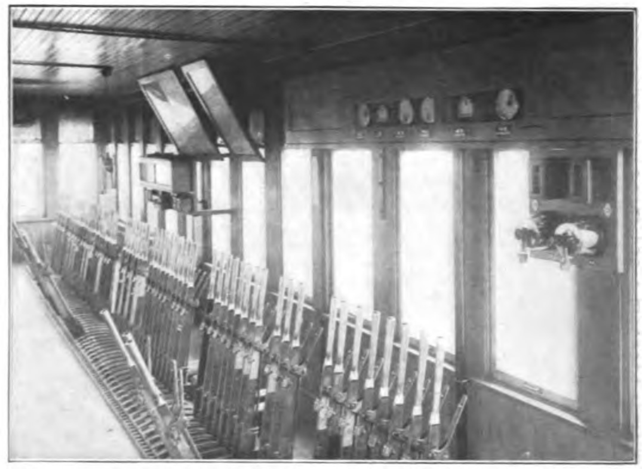
The high-tension transmission line is sectionalized at four points, approximately 5 miles apart, thus minimizing the zone affected in case of line failure. Two of these sectionalizing switches are located in the Elsdon substation, and the other two are on the pole line, as shown in the circuit plan. These outdoor type oil sectionalizing switches are General Electric Company's double-pole, single-throw type P.

SIGNALS

A typical signal control circuit is reproduced herewith. G. R. S. type K track transformers are used to transform the 110-volt current down to the track and lamp voltages. A separate track transformer is used for each track section. The signals are lighted by non-controvertible type lamps equipped with two 2-cp., 6-volt tungsten lamps burning in multiple. These are operated on 5 volts, as this gives sufficient light and very materially increases the life of the lamp. The wires are carried from the mechanism case up to the lamp in conduit.

The signals are of the G. R. S., model 2A bottom post type, operated by 110-volt, 60-cycle, single-phase induction motors. Double-mechanism cases are used, the lower compartment housing the relays, track transformers, track impedances, lightning arresters and terminal board. All wires entering the signal case are first carried to a hinged terminal board, and from this to the various functions. This hinged terminal board allows easy access at the back. Except in special cases, G. R. S., model 2A, three-position track relays, with 110-volt locals, are used for the signal control circuits. However, in every case where there are facing-point switches in the block, a separate 45-deg. line-control circuit is used, and this is broken through all facing-point switches. G. R. S., model 2B relays are used on these circuits. All switches are equipped with double shunt wires and this protection alone is relied on for the trailing-point switches.

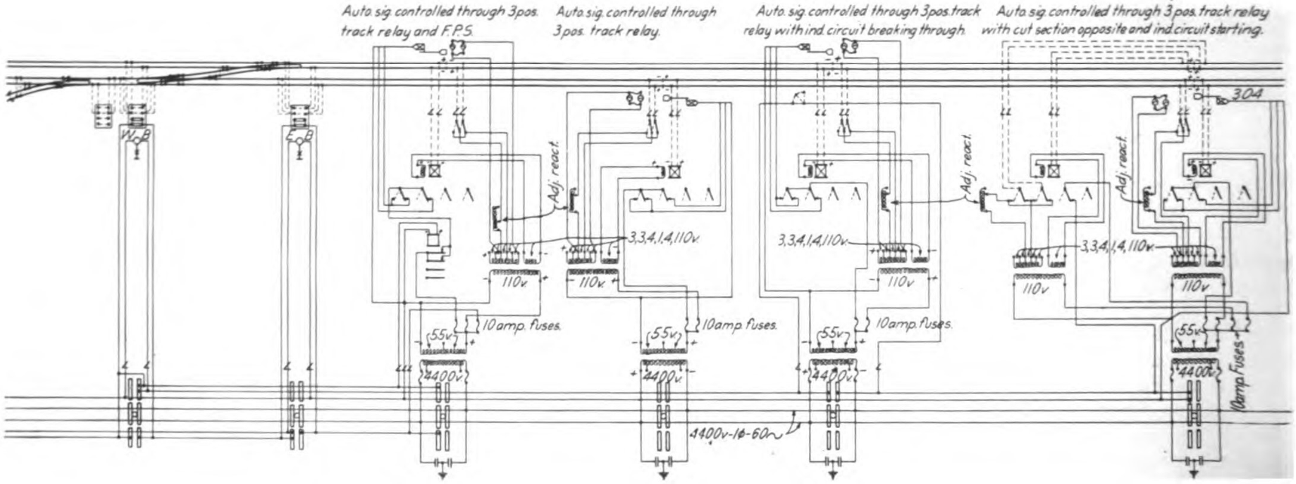
Switch indicators are provided for all main-line switches, except those located in yard zones where switching is constantly going on. In these cases the indicators would be in the stop position so large a proportion of the time as to be practically valueless. The indicators are normally energized, 0 to 90 deg., upper quadrant, semaphore type, it being felt that with the normally energized type there is less likelihood of trainmen neglecting to observe the indication. All indicators are clearly marked to show whether they refer to east or westbound traffic, as such information is of assistance to trainmen, particularly at crossovers, in familiarizing themselves with the use of the indicators.



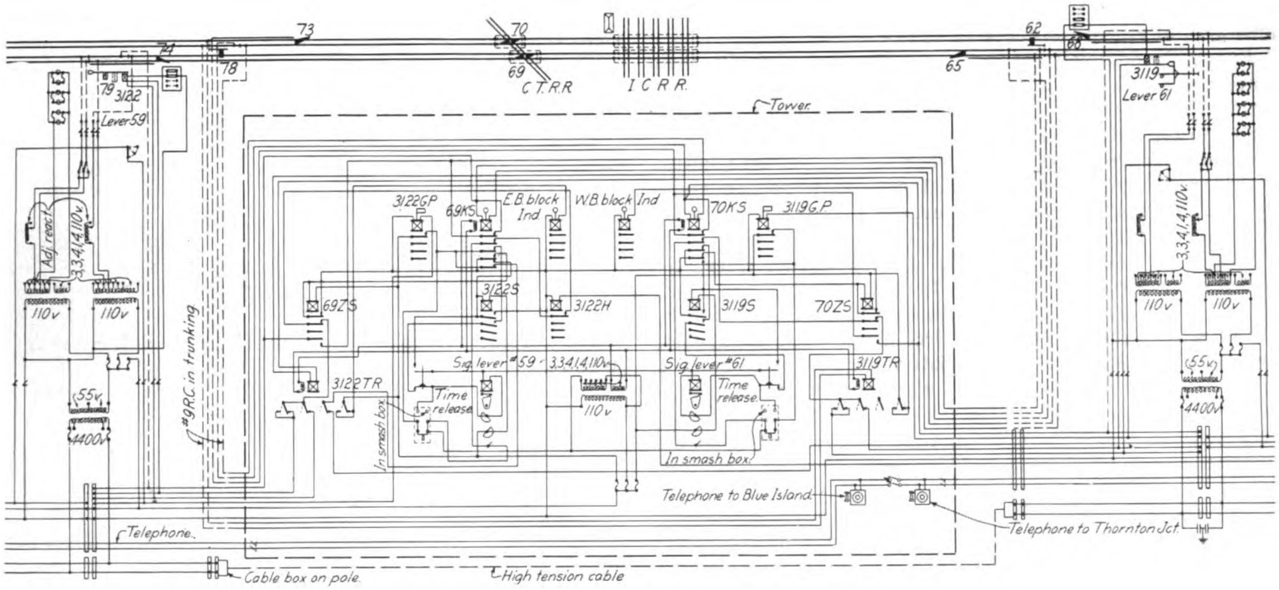
Interior of the Harvey Interlocking Plant.

INTERLOCKING

There are two interlocking plants within the limits of this installation. The crossing of the four-track main line of the Illinois Central and the B. & O. C. T. with the Grand Trunk at Harvey is protected by an 80-lever mechanical plant. The mechanical home and distant signals on the Grand Trunk were replaced by three-position, semi-automatic a. c. signals, incorporated with the automatic block system. A mechanical calling-on arm is installed on the eastbound home signal mast, but none on the westbound. As the westbound home signal block is very short, only extending 600 ft. beyond the back-up dwarf signal, and, further, as there were no switches in it, it was felt that any train passing the home signal would proceed through the block without stopping. Route locking was installed for the Grand Trunk high-speed routes. The circuit was adapted from the company's standard d. c. circuit, which is a stick relay circuit, requiring only one electric lock per route, this being installed on the home-signal lever. Back locking



Typical Signal Control Circuit.

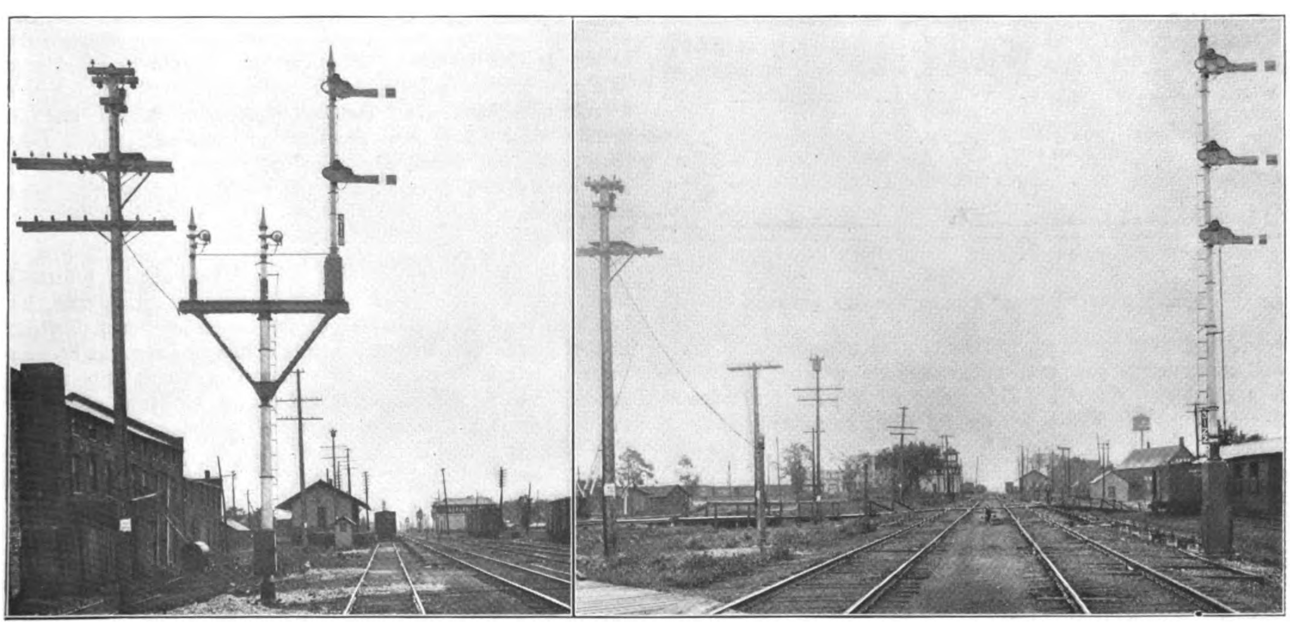


A. C. Route Locking Circuit at Harvey Interlocking Plant.

for the home and distant signals is effective at all times, route locking becoming effective once the home signal lever is reversed. Detector locking is provided for the high-speed route when the home signal lever is reversed. The latter feature allowed the removal of the crossing bars. Release from the route locking is obtained by a Union clockwork time release, set for one minute. The usual Grand Trunk practice is to set these releases for two minutes, but the extremely heavy traffic on the Illinois Central led to the adoption of one minute in this case. Emergency release for the detector locking circuit is obtained by breaking a glass smash box and reversing a double-throw, double-pole knife switch. This cuts out all the electric locking except back lock protection, but also prevents the use of the high-speed signal. After this emergency release has been operated, trains must move through the plant either on the calling-on arm, or by caution card.

As there are five Illinois Central tracks at this point, it was necessary to introduce a trap circuit in the Grand Trunk tracks. As the transmission line circuit might be opened momentarily during central station switching operations, provision was made for this track circuit to be self-restoring in case the source of power failed and then became alive again. It was also necessary to add a push button reset for this trap circuit, due to switching movements that did not pass over the entire circuit.

All tower wiring is enclosed in galvanized iron conduit. Wires upon entering the tower were first carried to a sheet steel terminal box and from this to the various functions. G. R. S. model B, a. c. electric locks were used with complete latch contacts. For each route, disc type indicators were provided for the track section between derails and the track section extending from the back-up dwarf signal to the next automatic block signal in advance. Semaphore type tower repeaters were provided for home and distant signals. All the relays and indicators were mounted in a neat oak cabinet, placed above and in front of the interlocking machine, thereby materially reducing the cross wiring in the tower. An oak panel is provided below the cabinet, on which are mounted the clockwork time releases, glass smash



Home Signals in the Harvey Interlocking Plant.

boxes containing the emergency release switches and the push-button resets for the trap circuit.

Approach annunciators are not provided, but in their place there is a telephone circuit to Thornton Junction interlocking plant on the east, and Blue Island interlocking plant on the west, and the levermen are required to advise the plant in advance of the approach of trains. In addition there is a listening set installed on the telephone train-despatching line, allowing the leverman to get information from the despatcher.

The 72-lever mechanical plant at Blue Island, where the Indiana Harbor Belt and the B. & O. C. T. cross the Grand Trunk, is practically the same as that at Harvey described above, except there is no trap circuit, and there is installed an eastbound approach annunciator, consisting of a. d. c. train drop and bell working off the back point of an a. c. disc type approach indicator. Four cells of BSCO battery operate the train drop and bell. This approach annunciator is required here, as there is no plant west of Blue Island for some 13 miles.

The plans and specifications for this entire installation were drawn up in the signal engineer's office of the Grand Trunk, and the work was installed under the supervision of this office. The signal work was done by the General Railway Signal Company, under contract. The pole line was built by the Grand Trunk telegraph department forces under the joint supervision of the signal and telegraph departments. The substation and equipment were built and installed by the General Electric Company under contract.

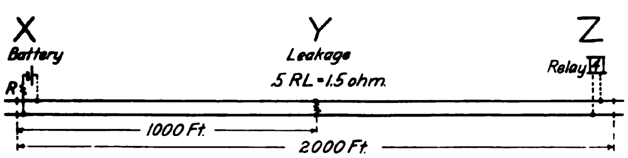
DETERMINATION OF RESISTANCE REQUIRED IN TRACK CIRCUITS

BY G. K. THOMAS

The only really accurate method of determining the value of resistance to be used in battery leads for feeding track circuits is to get on the ground during a heavy rain when the worst possible track conditions are experienced and adjust the resistance until the relay receives a current slightly in excess of the minimum pick-up value. This is not always feasible and it is therefore necessary to have some ready method of determining with fair accuracy what resistance is required in each case.

Assuming similar track conditions, it is obvious that the resistance required will vary with the length of the track circuit, therefore it becomes apparent that a table can be constructed giving definitely the resistance to be used for any length of circuit when certain minimum values of track leakage resistance are assumed.

The leakage resistance per 1,000 ft. of track may vary anywhere from a maximum of about 60 ohms to a minimum of about 2 ohms, according to track and weather conditions. However, the lowest resistance we would expect to find on a fairly well constructed track, even under very bad weather conditions, is 3 ohms per 1,000 ft. This value of leakage resistance is therefore used as a basis for the following calculations.



Typical 2,000-Ft. Track Circuit Showing Leakage.

Assuming that the leakage is uniform throughout the length of the circuit (end leakage included), it can be considered as concentrated at a point half way along the length of the circuit. The following assumptions are also made:

Volts at battery (BSCO or similar type) on closed circuit $= Eb = 0.68$ volt.

Resistance of relay coils $= Rr = 4$ ohms.

Current in relay coils $= C_2 = 0.1$ ampere.

Resistance of rails and bonds per 1,000 ft. of rail (assuming 90-lb. rail) $= Rt = 0.04$ ohm.

Resistance of battery leads to track $= Rl_1 = 0.12$ ohm.

Resistance of relay leads to track $= Rl_2 = 0.12$ ohm.

Leakage resistance per 1,000 ft. of track $= RL = 3$ ohms.

Taking for example the case of a track circuit 2,000 ft. long we have the conditions shown in the sketch. The voltage E Y across the rails at Y is equal to the C R drop in the circuit Y Z, including the relay coils;

$$\text{i. e., } E\,Y = C_2\,R_2 = C_2\,(Rr + Rl_2 + 2\,Rt) = .1\,(4 + .12 + .08) = .42 \text{ volt}$$

The current through the 1.5-ohm leakage resistance at Y must be

$$C_1 = \frac{E\,Y}{1.5} = \frac{.42}{1.5} = .28 \text{ ampere}$$

The total current fed from battery equals leakage current plus current in relay;

$$\text{i. e., } C = C_1 + C_2 = .28 + .1 = .38 \text{ ampere}$$

The voltage across the rails at X must be equal to the drop from X to Y plus the voltage at Y;

$$\text{i. e., } E\,X = (C \times 2\,Rt) + E\,Y = (.38 \times .08) + .42 = .45 \text{ volt}$$

The voltage at the battery, assumed to be .68 volt, is equal to the drop in the leads and resistance unit R plus voltage on rails at X;

$$\text{i. e., } .68 = C\,(R + Rl_1) + E\,X = .38\,(R + .12) + .45$$

$$\text{Therefore, } R = \frac{.68 - .45 - .0456}{.38} = .49 \text{ ohm}$$

In this manner the following values are obtained:

Length of circuit.	Resistance required.
500 feet	1.4 ohms
1,000 feet	.9 ohm
1,500 feet	.7 ohm
2,000 feet	.5 ohm
2,500 feet	.3 ohm
3,000 feet	.2 ohm

These values will, as a rule, insure proper operation of the circuits under varying track conditions and may be used when the battery is first installed. However, they should be considered only as a starting point with the realization that each circuit is a problem by itself. In order to promote both economy and immunity from failure it is necessary to make adjustments from time to time as found advisable, and a close watch should be kept on the circuits, especially for the first few months after installation.

Brownell's Automatic Stop.—A mechanical-trip automatic train stop, invented by George W. Brownell of St. Albans, Vt., has been tried on a sidetrack of the Central Vermont Railway at that place. Mr. Brownell places a ramp on the ties between the rails of the track and, by means of a sliding tripper, suspended from the locomotive frame, causes the lifting of a valve on the engine as the ramp is passed, applying the air-brakes. The ramp is moved into or out of position by a dog, turned by a shaft connected to the visual signal. To prevent trouble from freezing, the ramp is supported in a trough, which, in winter, contains salt. The air apparatus, on the locomotive, moves a piston in a double cylinder so arranged as to exhaust, at first, only a part of the air necessary to make a service application, further reduction, as may be demanded, being provided for by suitable adjustments.