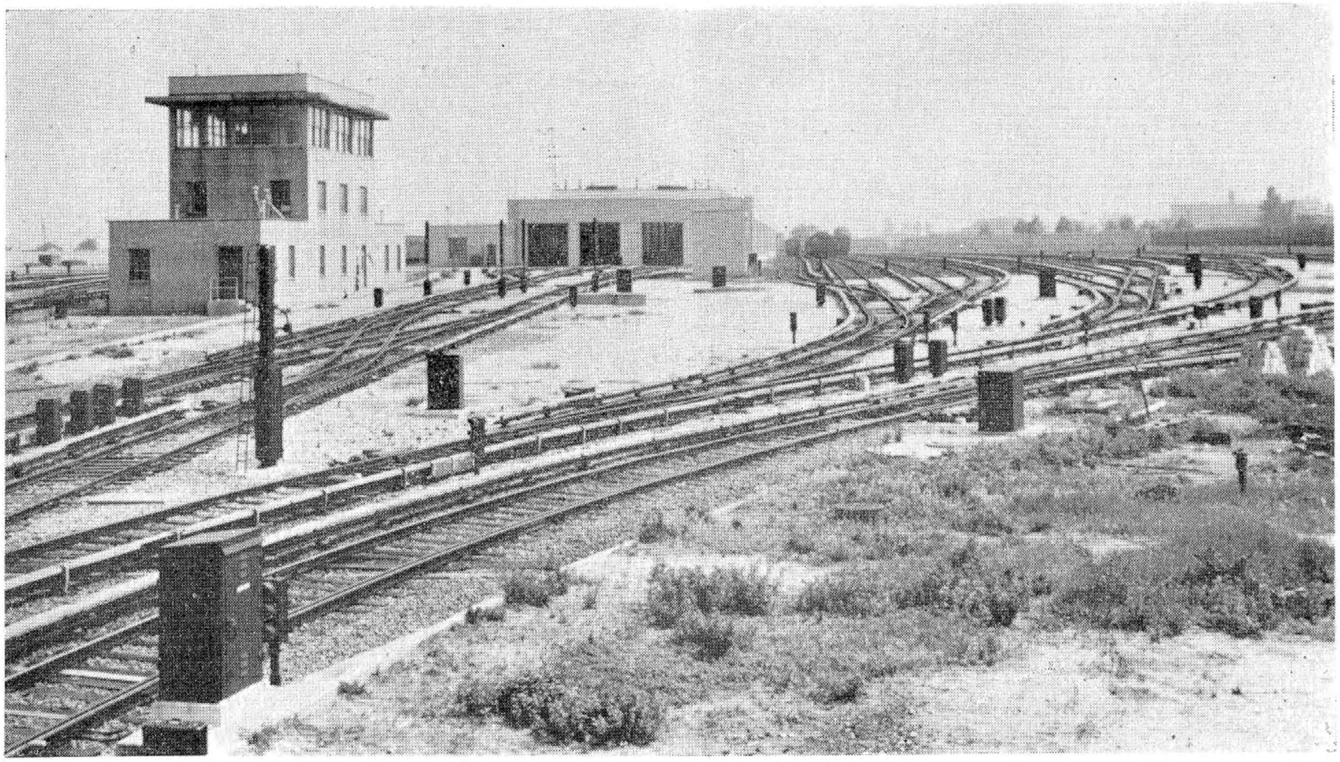


General view of part of the interlocking layout and tower at Pitkin Avenue Yard

Signaling and Interlocking

On New Line of New York Subways

Fulton Street extension, in Brooklyn, includes modern entrance-exit controlled interlockings, and automatic signaling with the new rectifier-fed control circuits

THE Board of Transportation of the City of New York has recently placed in service an extension of the Fulton Street line in the borough of Brooklyn from the East New York express station to the Euclid avenue express station, including a large open air yard known as the Pitkin avenue yard. The total length of the extension is approximately 2.5 route miles of four-track main line and two lead tracks to the yard. On the 11 mi. of main tracks there are a total of 60 automatic block signals in addition to the interlocking signals.

The signal control is based on a single-block overlap, which means that the signal will not change from the red aspect until the rear end of the train has passed the second signal in advance. This provision is used in order to have braking distance protection from a danger signal (red) to the rear end of the preceding train.

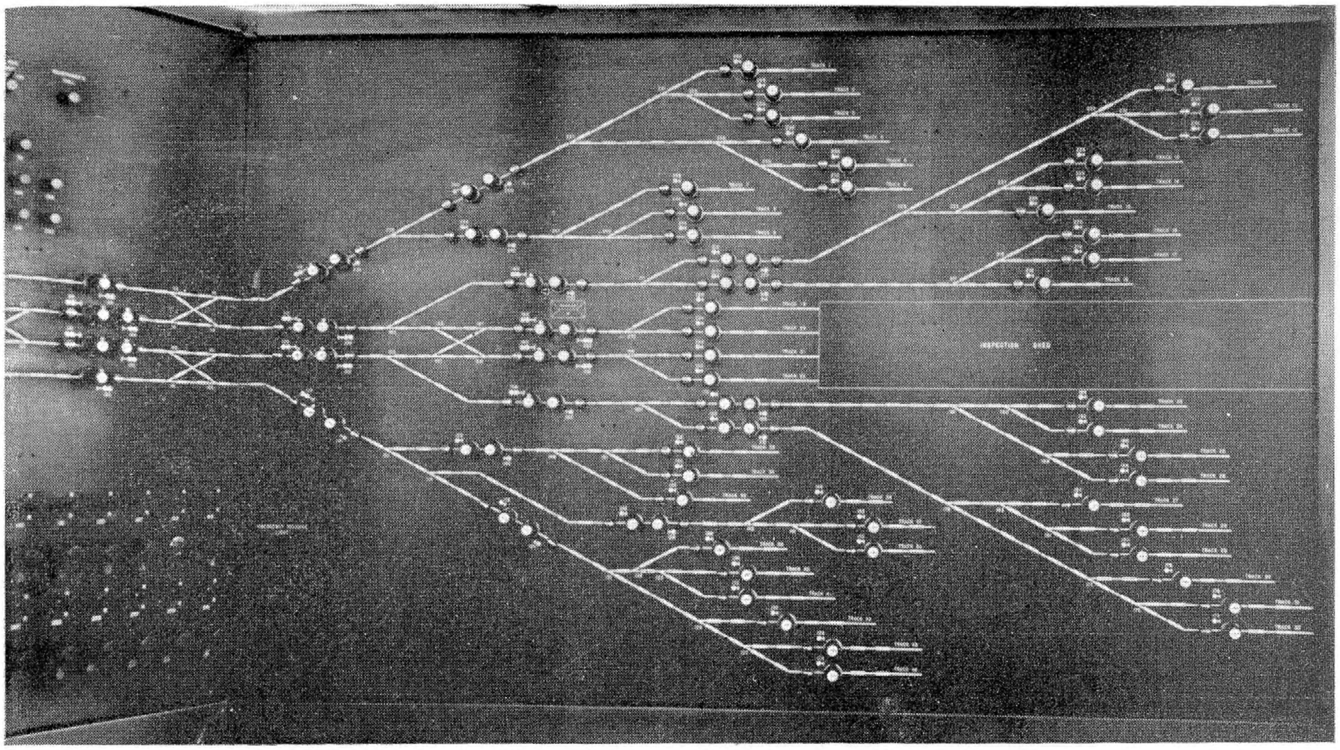
The obedience of stopping at a red signal, and therefore the protection indicated above, is obtained by using a power-operated automatic train stop or "trip" at each signal. When the signal is at danger, the automatic stop arm is in the raised or tripping position. If the motorman does not observe or obey the restricted aspect of the red signal, the arm of the automatic stop comes in contact with the trip cock on the cars of the train, thereby making an emergency brake application, and the train is brought to a stop before it reaches the rear end of the preceding train.

The signal system is laid out for a 90-second headway with 30-second station stops at local platforms and 45-second station stops at express platforms. The average operating speed for the signal layout is taken at 20 miles per hour for rush hour operation, but the signals are so located and spaced as to give maximum protection for the maximum speed obtainable for any run. The maximum train length is 605 ft. for the 10-car train.

The close headway and the fairly long station stops produce a "block" or track circuit which is relatively short, the average being approximately 17 track circuits per mile of track.

Grade-Time Signals

The maximum speed *obtainable* by a train in this section of subway is 52 m.p.h. However, a maximum *permis-*



Right panel of "NX" interlocking control machine at Pitkin Avenue Yard

sible train operating speed is limited to approximately 40 m.p.h. Limitation is obtained on descending grades by the use of "grade-time" signals which are normally-danger signals and will clear in advance of the train if the motorman restricts the speed of his train to the established predetermined speed. This in indicated in Fig. 1. In approach to a grade time section of track there is a sign designating the speed, such as "T-30"; indicating the limiting speed as 30 m.p.h. Track circuit No. 1, when occupied, controls a time-element relay which is set at a time in seconds which corresponds to the equivalent time for the length of track circuit No. 1 based on 30 m.p.h.

The next signal, No. 2 will, under normal-clear track conditions, display a yellow aspect, as indicated by the solid control line, and an illuminated letter "S". This letter "S" indicates to the motorman that the track circuit controls for the signal ahead, No. 3, are unoccupied.

As the train proceeds along track circuit No. 1 and the speed is below 30 m.p.h., the time relay will function and signal No. 3 will change from red to yellow and signal No. 2 will change from yellow to green and the letter "S" will go dark. This indicates to the motorman that he has obeyed the speed limitation, and can safely continue past that signal. At the same time as signal No. 3 aspect is changed from red to yellow, the "S" sign is illuminated on that signal, indicating that the track circuit for signal No. 4 is clear. This condition of signal No. 3 indicates to the motorman that he must repeat the same procedure in track circuit No. 2 as he used in track circuit No. 1 and maintain his speed at less than 30 m.p.h. With continued normal clear track conditions, the subsequent signals throughout a grade-time zone will operate in sequence, as described above as long as the average speed limit is observed.

If the motorman should not maintain his average speed below 30 m.p.h. in track circuit No. 1, signal No. 2 would not have its aspect changed from yellow to green and the motorman would then be forced to stop at signal No. 3, indicating red, unless he made a further reduction in his speed throughout track circuit No. 2. This track circuit No. 2 is therefore the second "block" clearing of the "two-block" grade-time control.

The "two-block" clearing system was developed by engineers of the Board of Transportation in order to give advance information to the motorman and thereby increase speed by not forcing the motorman to run directly against a red signal.

The "S" indication is in reality a distance signal indication which indicates that the track is clear for the length of the control of the next signal. If the "S" is not illuminated, a more restricted aspect (red) is given, and the time system is not effective and the motorman is forced to stop at signal No. 3.

The motorman quickly learns to control speeds to that which is posted. The above arrangement of grade time signals results in a maximum safe speed with even running, minimum of braking and no occasion for unnecessary stopping.

Station Time Control

As indicated above, during rush hours the trains are operated on the close headway of 90 seconds. Therefore, while one train is making a station stop, it is important in order to meet this 90-second headway that the following train is closing up the dis-

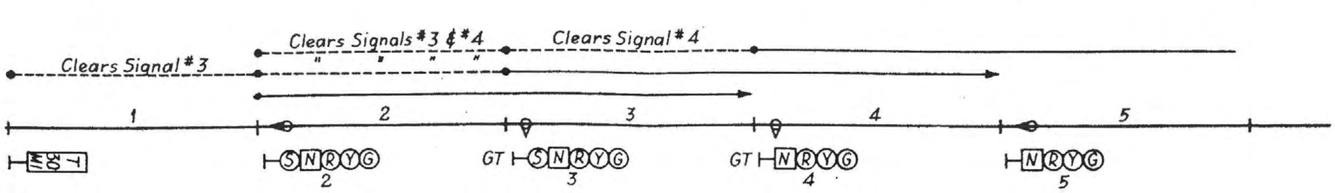


Fig. 1.—Typical grade-time signal control circuits

tance between the two trains, and approaching the entrance end of the station at reduced speed with a safe braking distance. This is accomplished by the use of "station time" signals. Due to the fact that the braking distances are limited, when clearing the station time signals, the time-element relay is controlled over only one block in advance of the signal instead of over two as in the grade-time signal control. To accomplish the close headway additional signals are installed between the point where the following train would normally (without closing-in or time control) be stopped for protection to the train in the station and the entering end of the station. Each one of these signals has its own track circuit or "cut section." The in the station moves out and the rear end clears track circuit No. 4, the following train after spending the required time on track circuit No. 2 clears signal No. 3 by cutting track circuit No. 5 from the control of signal No. 3 and thereby permitting the following train to approach signal No. 4 with absolute safety. This condition is repeated for signals No. 4 and No. 5.

Control Overlaps

It is to be noted that the control for signal No. 5 overlaps the leaving end of the station, or beyond signal No. 7, and that even signal No. 5 has its control cut back toward the leaving end of the station. This combination of controls permits a train to move a.c. single-rail type. The track relays are the G.R.S. plug-in type B, size 2, two-element vane, operating on 60 cycles, with 10 volts for the track circuit element and 110 volts for the local phase.

A.C. Rectified D.C. Circuits

All vital control circuits, except those in the interlocking network, fed from storage battery, are supplied with 12 to 14-volts pulsating d.c. from full-wave rectifiers at the feed end of the circuits. In an installation of this type, with all wires in cable, it would be inadvisable to use rectifiers at the relay end of the circuits, due to capacity effects between wires carrying a.c. energy which might, under certain adverse conditions, supply suf-

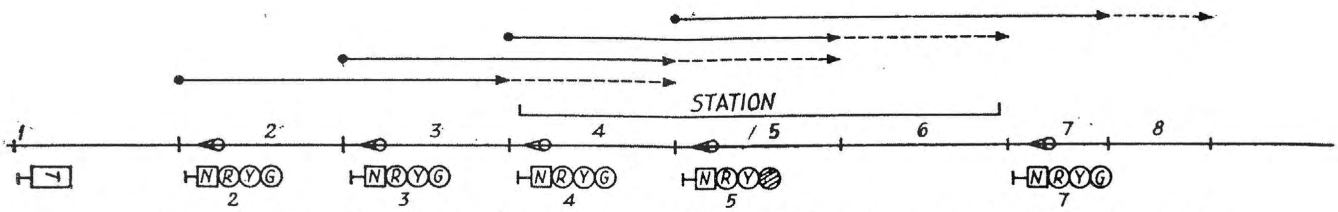


Fig. 2—Typical station-time signal control circuits—Dotted portion of controls are cut back by time

area within the station platform limits is also divided into "cut sections"; that is, short track circuits, which may vary from 66 ft. to 198 ft. This layout is shown in Fig. 2.

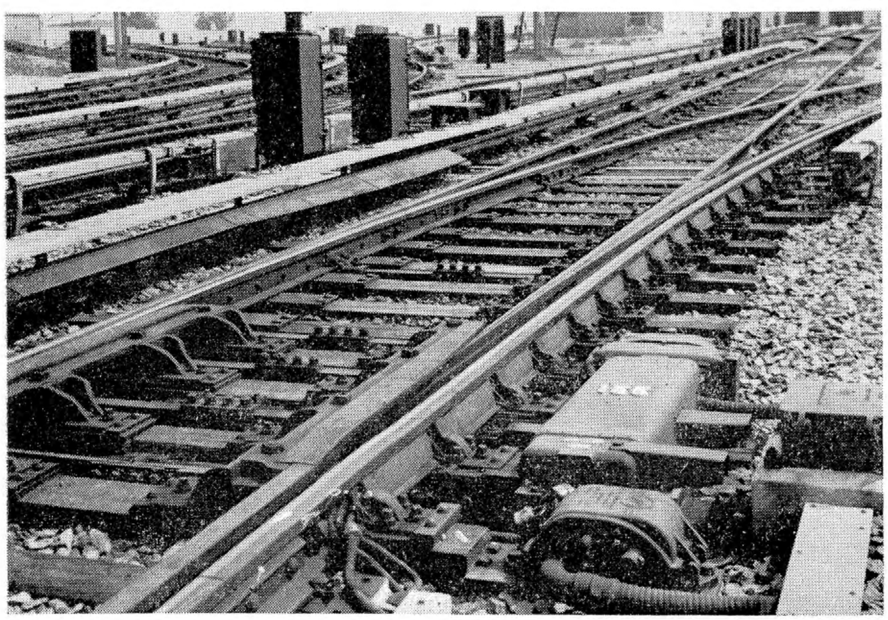
If a train is in the station with its rear end on cut section No. 4 and the following train passes the "T" sign (time), the motorman must reduce his speed in order to have signal No. 2 change from red to yellow. In doing so a timing device is operated and track circuit No. 4 is cut out of control of signal No. 2 because it is now safe for the motorman to approach the red signal No. 3. As the train toward an occupied station and in combination with the two trains moving into or out of the station in unison, a safe operating condition is in effect for a headway of 90 seconds.

The signal layout entering the station is such that if a following train is held at signal No. 3 before the train in the station starts to move, the train held at signal No. 3 will reach a station stop within 60 seconds after the first train has started to leave the station.

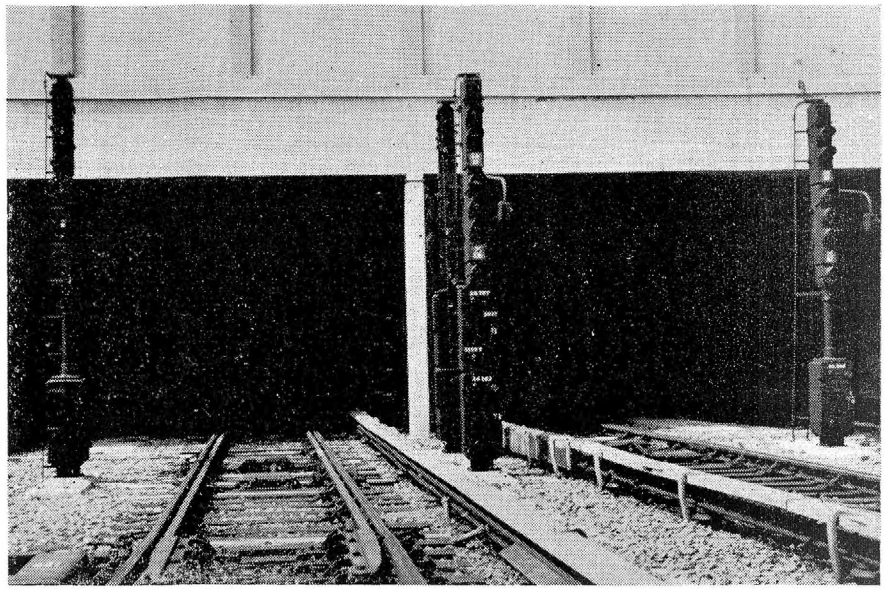
The electric traction energy used on this section of the subway is 600 volts d.c. The track circuits are the ficient energy to hold up relays after the controls are open or, in some instances, to actually pick up the relay, especially as 110-volt a.c. circuits were used as heretofore. The use of d.c., fed from rectifiers, for line circuits eliminates this potential hazard. Having recognized certain advantages of using d.c. signal control circuits and relays, the signal engineers of the Board of Transportation developed circuits which incorporate the advantages of both the a.c. and d.c. systems. This new a.c. rectifier d.c. circuit was used throughout in the new signaling on the Fulton Line, this being the first project to use such a combination of circuits.

The circuits are so arranged as to separate by means of individual rectifiers the "local" circuit, that is, the circuits from the instrument cases to the signals, track, automatic stop., etc., from the "line" circuit running from one location to another. By this means any ground in the "local" circuit will not affect any of the "line" circuits or vice versa.

A further new feature of this installation is that all the relays are the modern plug-in type, which makes it possible to replace a relay quickly and without the necessity of changing wire connections, which, with the previous



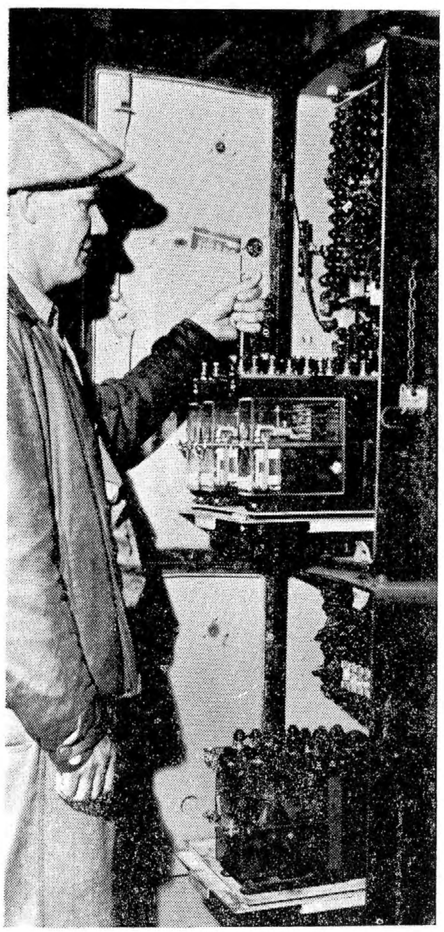
View showing electric switch machine, plates and rail braces at a switch in Pitkin yard



View of the new signals where the tracks from the open-air Pitkin Avenue yards enter the subway

types of relays was a serious delay and introduced a chance of making errors in connections. Also, the new plug-in relays are much smaller, thereby permitting the use of fewer and smaller relay cases which is an important advantage in the subway where space is limited.

Another new feature is that this project includes a special telephone circuit for the exclusive use of signal maintenance forces in working with one another or in calling the towermen or dispatcher. Each man has a small-sized portable handset which he can plug into any one of numerous re-



Relay on sliding shelf

ceptacles located at signals, instrument cases, power switches, relay rooms and other places where he may be working.

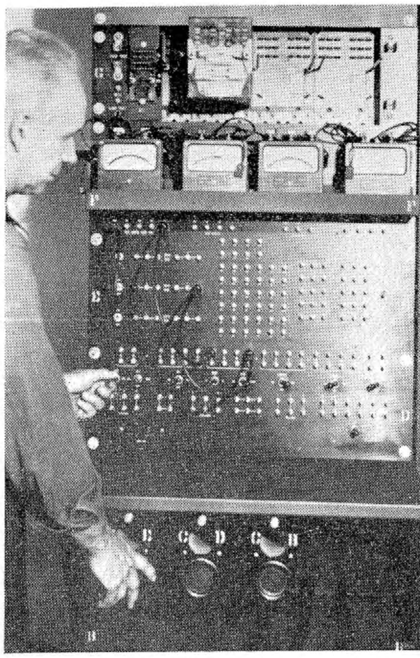
The recently completed extension of the Fulton Street line includes two important interlockings with NX control panels and line-of-light indications. The interlocking track layout at Euclid Avenue station involves four through main tracks and two junctions. One of these junctions is with a double-track line diverging to the Pitkin Avenue Yard. The second junction is a future double-track line which is to be connected to the existing BMT elevated line via Grant Avenue station to the terminal at Lefferts Avenue. This new Euclid Avenue interlocking includes 33 electric switch machines and 33 signals, all of which are controlled from an NX type machine in the tower at the east end of the station platform.

The interlocking at the Pitkin Avenue Yard includes 66 electric switch machines and 97 signals, which are controlled from an NX machine in a tower at the yard entrance as shown in one of the accompanying pictures. The overall construction and operation of these two plants are similar, and, therefore, the following explanations will be confined to the Euclid Avenue interlocking. The NX interlocking machine at Euclid Avenue has a center panel 6 ft. long and each of two wing panels is 3 ft. long, thus totaling 12 ft. length, and 40 in. height. The machine cabinet was designed to mount the panels at a height that is convenient for a man to operate the controls when standing or when seated on a high stool.

This control machine includes some new and interesting features different from other NX interlocking machines installed on other railroads, as explained in previous articles in this magazine. On the Euclid Avenue control machine, the tracks are represented by what appears normally to be a white line 1/8 in. wide. Actually in these white lines are a series of white tubular pieces of glass approximately 3/4 in. long. When an entrance knob is operated to initiate the setting up of a route, a red lamp in the face of that knob is lighted, and the 3/4-in. light sections immediately adjacent to all exit buttons, the routes of which are not being used, are illuminated white.

When the towerman pushes the exit button for the route he selects, the line-of-light section adjacent to the entrance knob is illuminated white, indicating that the selection network has functioned. At the same time the switches start to operate. The switches and crossovers are represented on the diagram by short track lamp sections which flash red (transit lights) when the corresponding switch is in operation. If a switch is already in the position called for, the track lamp sections representing that switch are illuminated with a steady white light. When all the switches are in position called for by a route being established, all the track lamp sections throughout the entire route are lighted white, and the signal and automatic stop begin to clear. The lamp in the face of the entrance knob changes from red to yellow when the signal clears. When a train accepts and passes a signal, the lamp in the entrance knob is extinguished, and the lamp sections representing the track occupied are lighted red, instead of lighted white. When the train passes beyond home signal control limits, the track lamps are extinguished.

If an occasion arises for cancelling an established route before a train accepts the signal, the towerman pulls the entrance knob, and the lamps in the knob and the lamps in the "track" go out. If the track lamps stay lighted, this indicates electric locking is in effect under either approach or time control, and, therefore, the route is being held. When the route is released, the track lamps go out. Approach locking is provided for train movements in the normal direction of



Maintainer using test panel in the tower at new subway interlocking

traffic, and time locking for reverse moves.

Ordinarily the switches are controlled automatically as part of the NX system as previously explained. However, when making tests or adjustments on switches, there may be occasions when each switch must be controlled individually. This result is accomplished by small toggle levers, one for each switch or crossover, these levers being mounted in a row below the track diagram on the control machine panel. When the maintainer is adjusting a switch, and wants it operated from one position to the other, he telephones his request to the towerman, who throws the corresponding toggle lever. When the work on the switch is finished, the maintainer advises the towerman, who then places the toggle lever back in the normal center position, thus returning the control to the NX system. These toggle levers are also used for establishing a predetermined route, if desired, where there is more than one possible route to an exit point.

Emergency Release

In special emergencies, it may be necessary to operate some switch with the detector track circuits out of service. To meet this emergency, this NX control machine is equipped with an emergency release which includes a special push button below the toggle lever for each switch. If a switch is to be operated independent of track-circuit-controlled electric locking, the signals must all be placed at Stop for a certain length of time. Then the towerman, on the authority of the dispatcher, breaks a lead seal and removes a cap from the button under the toggle lever for that switch. Then he operates the toggle lever to the position desired and pushes the emergency button and holds it in until a stick relay operates. An indicating light is provided to show that the stick relay has been picked up. After the indication light is illuminated, the towerman pulls the release button and holds it until a special emergency time release relay operates. When the switch is operating, the red switch-transit lights begin to flash, the emergency button is held in its pulled position until the transit lights are extinguished. The route can then be established by operating the entrance and exit buttons. If the switch toggle lever is moved while the emergency release is being operated, the stick relay will drop out and it will be necessary to start the operation again with the push of the emergency release button. The cap is then replaced on the button and is sealed as soon as practicable by the proper person.

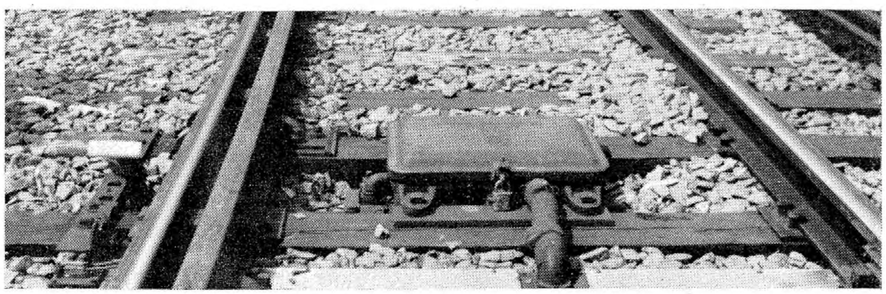
End-to-End Control

Each individual signal can be controlled by its respective entrance knob and corresponding exit buttons. However, for a train movement through the entire interlocking, the whole route can be established by operating the entrance knob at the first home signal, and then the exit button at the far exit of the plant as a whole. This is called "through-routing," and is in effect with no special action on the part of the leverman.

When a route is to be used by two or more following trains, "fleeting" control can be established to hold that route and to clear the signal again as soon as a train clears the home signal control limits. This fleeting control is established by pushing the entrance knob, as previously discussed, and then when the red light appears in the button, the knob is also turned 90 degrees. To cancel the "fleeting," the towerman turns the entrance knob back to its normal position. This can be done before the last train of the fleet passes. To cancel the route after canceling the "fleeting," he pulls the knob as previously explained.

Call-On Control

When making up trains, i.e., adding cars or taking off cars, it is necessary to authorize movements into occupied track sections. In such an instance, a motorman stops his train just short of the signal. Then the towerman operates the proper entrance knob and exit button, in the usual manner, and, in addition, he operates the call-on button associated with the control of that signal. The call-on buttons, one for each signal, are in a group on the panel above the track diagram. This use of a call-on button, following operation of an entrance knob and exit button, causes a call-on aspect, red-over-red-over-yellow, to be displayed on the signal. As special information to the towerman, the yellow lamp in the knob is flashed, until the motorman reaches out of his car window to operate a handle on a "key-by" mounted on the wall of the subway. This causes the trip stop beside the track to be lowered so that it will not stop the train. Then the flashing-yellow light in the entrance knob on the control machine changes to a steady yellow. This procedure compels cooperation between the motorman and the towerman when unusual operation of a signal is necessary.



Typical train stop location

In the instrument room, there is a special panel for testing plug-in type relays, as shown in one of the accompanying pictures. Four meters are mounted on a shelf just below the relays. Below the meters is a panel board with lamps which indicate the opening and closing of the contacts of the relay being tested. Also on the panel are the fuses and plug receptacles for connecting jumper cords to establish various test connections.

Automatic D.C. Ground Detector

This interlocking includes automatic ground detectors to detect and indicate grounds on the various d.c. mains used in the tower circuits. The mains are various voltages, 12 volts for the live circuits, 24 volts for the selection network and 110 volts for track switch operation.

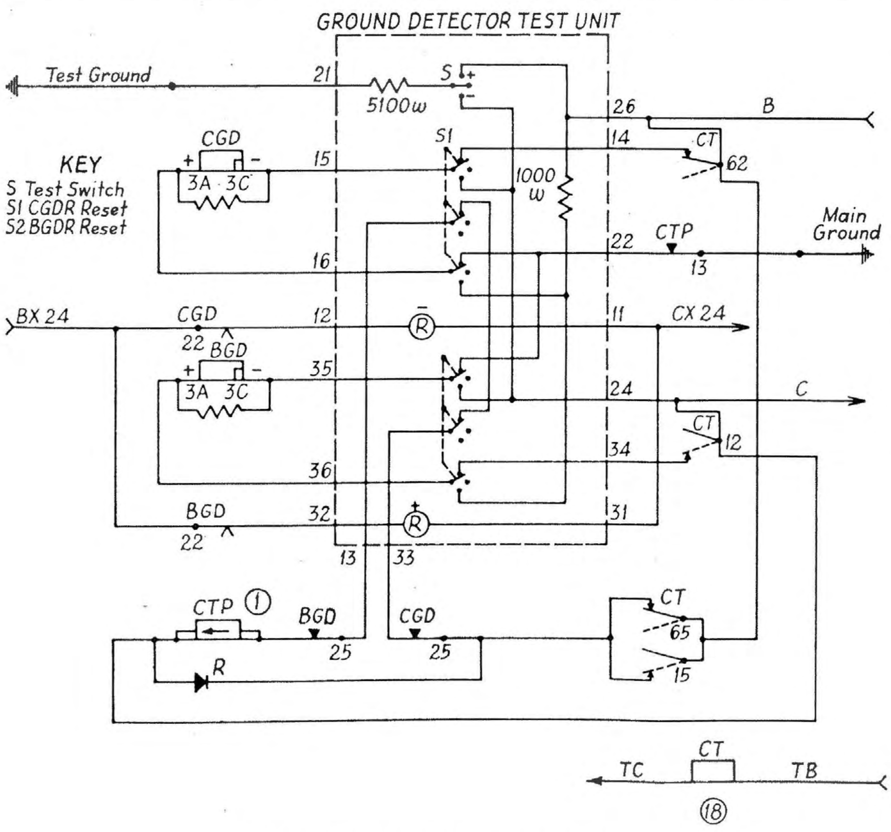
Each detector system includes a test unit, code transmitter, code transmitter repeater and two 520-ohms magnetic stick type relays; one to detect negative grounds and the other to detect positive grounds. A code transmitter operating at 75 times each minute, alternately applies positive and negative energy to the ground detector relays through the test panel which also connects the relays to ground. If a positive ground exists, the relay B-GDR will be tripped by the code transmitter closing the contact which applies negative energy to the relay coil. Being a magnetic-stick relay, this relay will remain in this position until manually reset.

The test panel is 2 in. wide and 6 in. high and has two indication lamps and three small toggle type switches. The "minus" lamp is lighted when a negative ground detector relay is tripped, and the "plus" lamp is lighted when a positive ground detector relay is tripped. The switch "S" is operated from its normal center position to the left position to apply an artificial plus test ground which should trip the "plus" ground detector relay and light the "plus" ground indicating lamp. Operation of the "S" switch handle to the right applies an artificial minus ground which should trip the minus ground detector relay and light the minus ground indicating lamp.

The "S1" switch is for the direct control of the "minus" ground-detector relay. Normally this switch is in the lowered position which connects the "minus" relay in the circuit to detect a "minus" ground. If the relay is operated to detect a minus ground or if it is tripped in a test as explained above, then switch "S1" must be thrown to the "raised" position, which connects minus energy to the relay to restore it to its normal position. If a "minus" ground has been detected automatically by the system, and switch "S1" has been thrown up to reset the relay, then the switch is placed in the center position while hunting for the ground. When the switch is in the center position, the relay is disconnected from the circuit. Switch "S2" operates in a manner similar to that explained for "S1", except that "S2" applies to the "plus" relay.

Adjustment of sensitivity of the ground detector relay is accomplished by means of a shunt across the relay (the higher the resistance value, the more sensitive the relay). The code transmitter repeater relay repeats the energized position of the ground detector relays and also checks that switches "S1" or "S2" are in their normal positions. If the code transmitter stops or switches "S1" or "S2" are left open, the code transmitter repeater relay will drop out and the indication will be the same as if a ground had caused one of the ground detector relays to be tripped.

When a ground occurs on one of the d.c. mains, a red light will be illuminated on the interlocking control panel, and the alarm bell will ring. To silence the bell, the towerman pushes the bell cut-out button, located under the red indicator light. The code transmitter repeater relay also disconnects the ground from the test unit when either ground detector relay is de-energized.



Circuit for ground detector test unit

Power Supply

The electric switch machines are operated on 110 volt d.c. which is supplied from a set of 96 cells of Edison B6H storage battery. The automatic train stops are operated direct from 110-volt, 60-cycle mains. A set of 18 cells of the same type of battery feeds the NX circuit network in the tower including the push-button stick relays. The reason for feeding these circuits from battery rather than rectified a.c. is to prevent loss of stick locking if the a.c. power is interrupted. As stated previously, the signal control circuits in automatic block as well as at interlockings outside the tower are energized at 12 to 14 vlt. from rectifiers.

The wires from cases to the Raco bootlegs at rails for track circuit connections are No. 9—19 strands, copper, rubber insulated with Neoprene sheath and are run in conduit imbedded in the concrete roadbed. The control and indication circuits in automatic block, as well as in interlockings, are in No. 14—19 strands copper wires in aerial cable, and are run on 5/16-in. stranded Copperweld messenger on hangers attached to the concrete wall of the subway. Where there is a possibility that sparks from the third rail might strike cable, the cable is covered with asbestos sheathing. The insulated wire and cables on this entire project were furnished by the Okonite Company. The single-conductor wire in the instrument cases and relay rooms is No. 14 for instrument cases and No. 16 on racks in the relay rooms stranded with 2/64 in. rubber insulation and 1/64 in. outer wall of Neoprene.

Insulated nuts are used on all terminal posts on the boards in the relay room in the tower as well as in all the relay cases at various locations along the track.

This automatic block signaling and the interlockings on this Fulton Avenue extension of the subways was planned by railroad forces under the direction of C. A. Reed, Engineer, Line Equipment, Board of Transportation, New York City Transit System. The construction was done under Mr. Reed's direction by the Emmerson Garden Electric Co. The signal and interlocking equipment were furnished by the General Railway Signal Company.