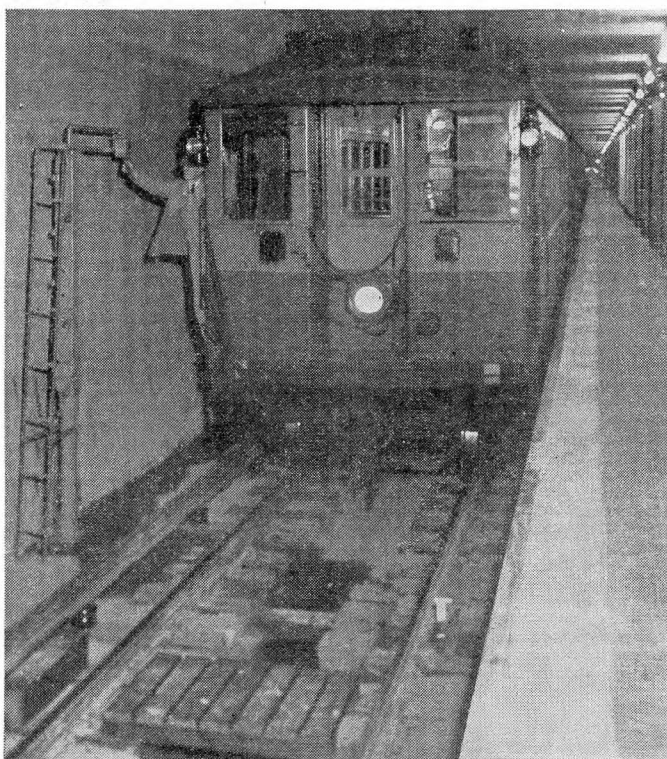




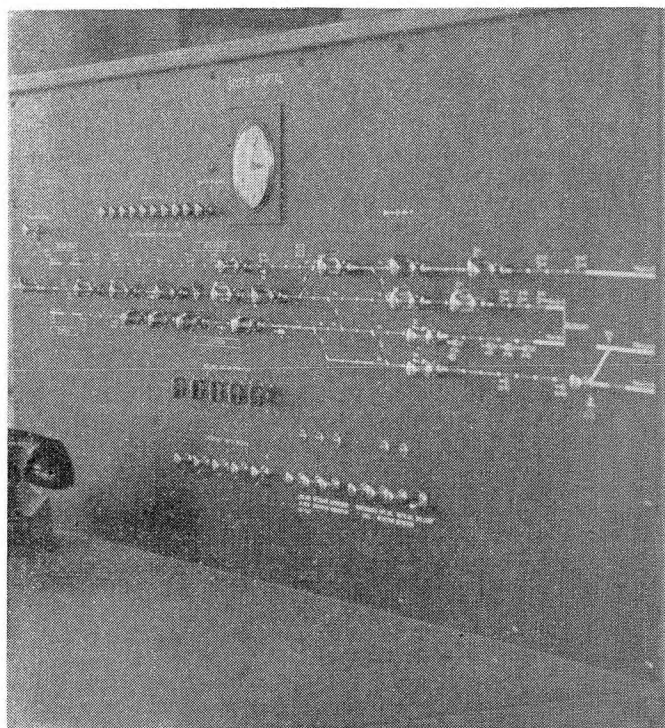
View of track along a station platform with an automatic signal at the right. Below — Motorman operating the release at an automatic signal.

## Automatic Signaling, Train Stop



ROUTE No. 1 of the Chicago Subway system, placed in service in October, 1943, includes modern automatic block signaling, automatic train-stop equipment, and 3 all-relay route-control interlockings. This Route No. 1, the first portion of a proposed extensive subway system, connects with the North Side Elevated Lines near Armitage and Sheffield avenues, extends southeast in Clybourn avenue, east in Division street and south in State street to a connection with the South Side Elevated Lines near Seventeenth street, the total length of the double-track subway being 4.9 miles. Route No. 2, which is 3.85 miles long, connects with the Northwest Elevated Lines near Milwaukee and Evergreen avenues, extends southeast in Milwaukee avenue, east in Lake street, and south in Dearborn street, where it is to continue west in Congress street to a loop east of the river. This route No. 2, now about 80 per cent complete, will be finished as soon as war conditions permit. Plans for future subways include al-

**Automatic signaling for 40 trains each hour includes time-distance-speed controls on decending grades and on approach to stations—Three interlockings are especially designed for rapid change of line-up**



Panel of the UR interlocking machine at the South Portal

# and Route Interlocking

## Installed in the Chicago Subways

most 42 miles of additional subways to be constructed as finances become available.

### Utilization of Route No. 1

The purpose for these subways is to extend local rapid transit facilities, expedite train movements and ultimately to permit the removal of the elevated track structure in the downtown area. The "L" trains now operating through subway Route No. 1 from the South Side Elevated to the North Side Elevated and vice versa formerly operated on the elevated structure in the downtown area and now save from 7 to 22 minutes daily for each of thousands of passengers.

A further advantage is that the stations on the new subway are located more conveniently with reference to important stores and office buildings. Another is that the subway goes under the Chicago river,

whereas the elevated crosses the river on a drawbridge, and quite often this bridge has to be raised for the passage of a boat, with the result that trains operating on the elevated structures are seriously delayed.

Since the subway was placed in service, the traffic has increased rapidly, not only because of the improved service, but also due to the fact that the rationing of tires and gasoline has forced many persons to abandon automobile transportation and use the rapid transit lines.

### Track Layout of Route No. 1

Not all of the trains to and from the south or the north use the new subway, and, therefore, the track layouts at the portals were designed so that trains can be routed to or from either the subway or the elevated structure through the downtown area. The North Side Elevated

includes four main tracks, the two center tracks for express trains and the two outside tracks for local trains.

The subway is double track and all trains stop at all stations. In order that trains from any of the four tracks from the north can be routed to either track in the subway or vice versa, the track layout at the north portal was designed with crossovers and switches, as shown in Fig. 2, in which the tracks from the subway emerge on an ascending grade as the two middle tracks, with two elevated tracks on each side. This layout includes 8 crossovers, 2 single switches and 34 signals, which are controlled by an all-relay route-control machine in a tower at Armitage avenue.

South of the south portal at Seventeenth street, the South Side Elevated has three tracks, one track on each side is for local stops as well as for certain through trains, while the center track is for through express trains between Seventeenth street and Indiana avenue, this track being used in one direction or the other depending on the preponderance of traffic; for example, northbound in the morning inbound rush hours, or southbound in the evening outbound rush. In order that trains can be routed in either direction between the three-track elevated lines and either the subway or the elevated north of Seventeenth street, the track layout is designed as shown in Fig. 3. This layout includes 4 crossovers, 1 single switch and 17 interlocking signals, which are controlled by an all-relay route interlocking machine

in a tower north of Eighteenth street. The details of the construction and operation of these interlockings will be explained later in this article.

Where the subway under State street turns east to connect with the elevated structure at Thirteenth street, excavation was made and bulk-headed for a future extension south under State street. The northbound tube of this future extension, built at a lower level to provide grade separation, is equipped with a stub track with a Y connection to the present tracks and can be used to double back trains from the north. This track layout consists of three switches and 10 signals controlled from an interlocking machine.

On the 4.9 miles of double-track subway between North Portal and

mechanisms which are equipped with electric locks, the control of which will be explained later.

### Automatic Block Signaling

The automatic block signaling in the subway is arranged for train operation in one direction only, right-

the train line thus causing an emergency application of the brakes on the entire train.

The red aspect of any of the automatic block signals indicates Stop-and-Then-Proceed. When the train stops, the motorman must lean out his window to operate a stop release, mounted near the signal, which causes the trip

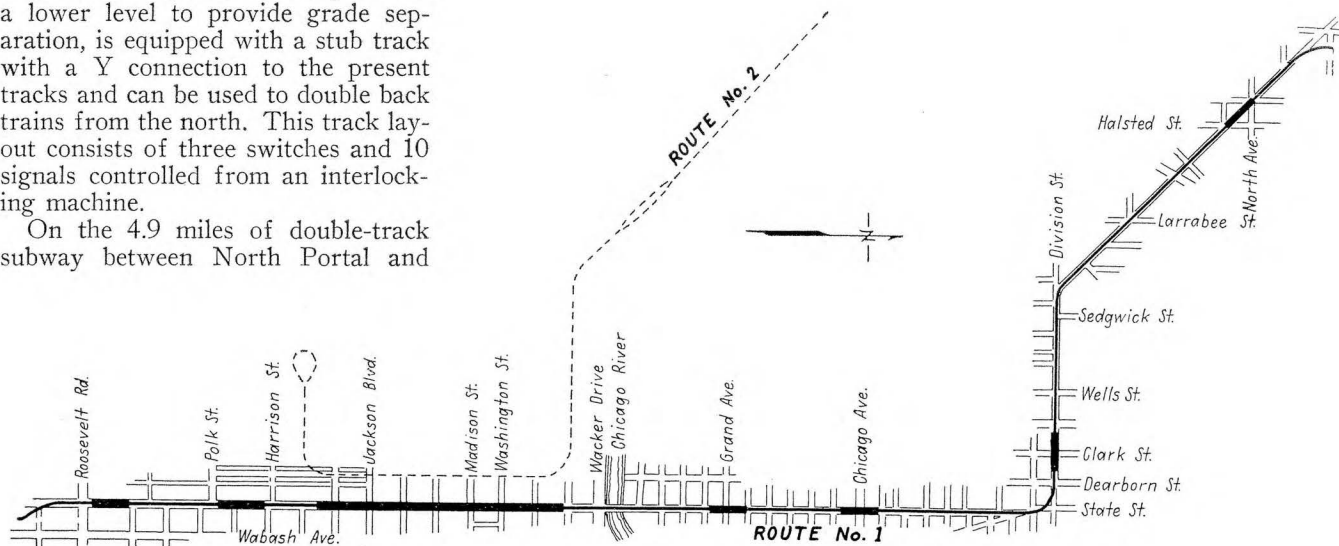


Fig. 1—Map of the Route No. 1 of the Chicago subways

South Portal, trains are ordinarily operated right-hand running. In order to permit maintenance forces to work on a section of track, all trains in both directions can be operated on the other track during slack periods between 2 a.m. and 5 a.m. In order to sectionalize the tracks for this purpose, there are two sets of diamond crossovers, one just south of the sta-

tion at Grand avenue and the other south of the station at North avenue. These crossover switches are operated by hand-operated switch-and-lock

arm to be lowered to its normal position, thus allowing the train to pass without the brakes being applied.

### Track Capacity Determined by Train Speeds, Spacing Between Trains and Braking Distances

The automatic signaling was planned to attain two objectives; to operate the trains at the maximum

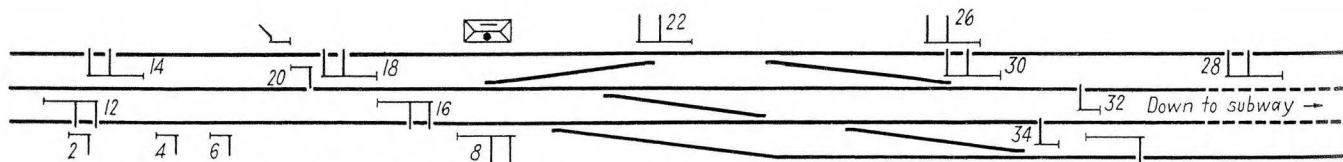


Fig. 2—Track and signal plan of the interlocking at the South Portal

where it will strike and operate an air valve on each car of a train, if the train is driven past the signal. Operation of this valve releases the air in

speeds which are practicable in consideration of the spacing of stations and the tractive effort of the equipment, and also to get as many trains

speeds which are practicable in consideration of the spacing of stations and the tractive effort of the equipment, and also to get as many trains

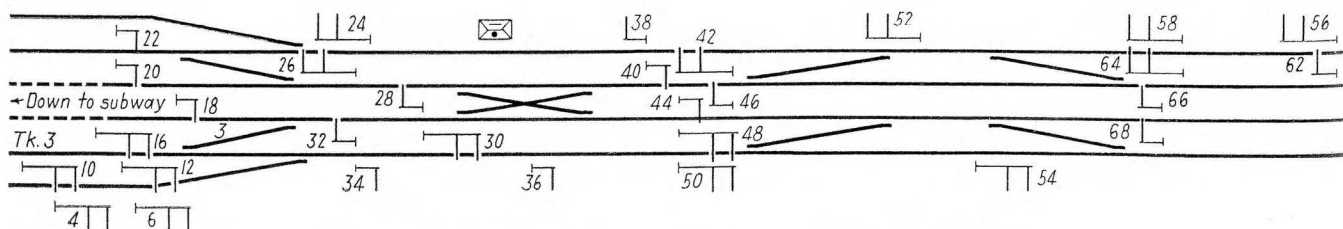


Fig. 3—Track and signal plan of the interlocking at North Portal

over the line as possible by reducing the space between trains to a minimum that is consistent with that required to stop short of a train ahead.

On this basis, for the normal run-

an hour. On ascending grades the train braking distance is shorter and, therefore, the block lengths can be correspondingly shorter, thereby automatically reducing the space be-

grades. In consideration of all these factors, the speed of trains when descending grades is limited by rule to certain maximums as marked on signs along the track, and the signal-

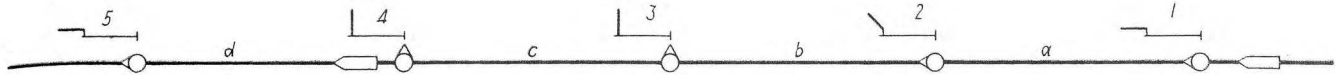


Fig. 4—Diagram showing control limits of signals and train stop

ning speed between stations the minimum spacing of signals is the distance required to stop a train running at maximum speed with an emergency application of the brakes, plus a short distance as a factor of safety.

As mentioned previously, the train-stop arm at a signal is in the raised position only when the signal displays the red aspect, which may be with a train stopped just beyond the signal. Therefore, in order to provide automatic train-stop protection for train braking distance, as shown in Fig. 4, the second signal in the rear of the train is held at stop with its train-stop raised to the tripping position. This means that the red aspect of each signal is controlled not only for the length of its own block but also by the next one as well, this being termed one-block overlap signal control. Thus referring to Fig. 4, signal No. 4 as well as No. 3 display the red aspect and signal No. 2 displays the yellow aspect until the rear of the train passes signal No. 5. Therefore, if trains are to operate at normal maximum speed on green signals, the minimum spacing from the rear of one train to the head end of the next must be equal to the total of the lengths of the four blocks, a, b, c, and d, and each of these blocks is at least equal to the train stopping distance plus a factor of safety. This total distance between trains reduces the number of trains which can be operated past a given point in a certain time.

### Eight Cars To a Train

The design is for cars each 48 ft. 6 in. long, and for 8 cars to the train. Furthermore, the volume of passenger traffic in rush hours established the ruling that the signaling should provide for the operation of trains on 90-second headway, i.e., 40 trains

tween following trains to compensate for the reduced speed when ascending the grade.

### Descending Grade a Different Problem

At North Portal, the line descends from the elevated structure to the subway level, at a grade which, for the most part, is about 3.0 per cent. A similar grade extends where the subway tracks emerge and climb up to the level of the elevated structure at South Portal. Also 3 per cent grade from each direction extends down to the portion of the subway under the Chicago river.

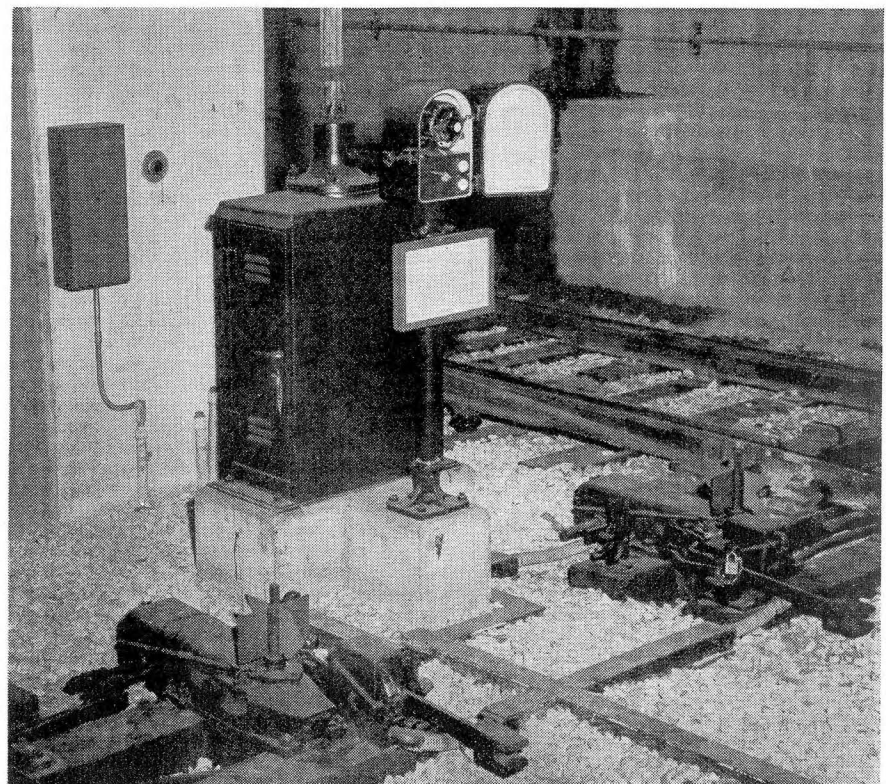
If trains were allowed to operate at maximum speed when descending these grades, the train stopping distance would be much longer than on level track because of the effect of gravity. Long blocks would increase the space between trains and thus reduce the track capacity below the fixed limit of 40 trains per hour. Furthermore, from the standpoint of safe train operation, the speed must not be too high when descending

ing and train-stop system include special grade-time-distance controls arranged so that the brakes are applied automatically if this maximum speed is exceeded. The speed is measured on the time-distance basis. When a train enters the block, the release of the track relay starts the operation of a time-element relay which is set to operate its cycle before the train passes the next signal, if the speed is 25 m.p.h. or less.

### Typical Grade Timing

A typical layout for "grade-timing" signaling is shown in Fig. 5. Normally, i.e., with no train occupying the automatic blocks shown, the signals 14 and 13 display the red aspect, signal 12 yellow and lunar white, and signal 11 the green. Signals 12 and 13 are each equipped with a lunar white marker which is lighted only when the signal displays the yellow aspect and there is no train in the control limits of the next grade time signal in advance.

As a train approaches the time sign at signal 11, the motorman should



View at switches of emergency crossovers showing T-21 manually operated switch-and-lock mechanisms with electric locks on the levers, as well as the clockwork time release and lamps on the case with door open

reduce the average speed of his train in block "a" to the limit posted on the sign, and if this is done, the aspect of signal 12 will change from yellow to green before he passes it, and prior to this, the train stop at signal 13 has been lowered and the aspect of that signal changed from red to yellow and lunar white. If this change does not occur, he knows that he must make a further reduction in speed throughout block "b" so that his average for the two blocks ("a" and "b") will be less than the posted limit. If so, before he arrives at signal 13 the train-stop trip will be lowered and the aspect will change first from red to yellow and then, after signal 14 has cleared, to green. On the other hand, if the speed is not reduced according to posted limit and the train cannot be stopped short of signal 13, then the train-stop is effective in applying the brakes. Such occasions, however, are very rare. The motormen soon learn to gage the speed so that they can run very close to but not exceed the speed limit, and thus the aspect

as for longer blocks at higher speeds. For this reason the uniform flow of traffic is not interrupted.

### Approaching Stations

The duration of a train stop at a station varies from 20 to 60 seconds. In the meantime, if trains are being operated on a 90-second headway, the next train is approaching the rear of the train which is then standing at the station platform. Under these circumstances, the desirable objective is to provide for the approaching train to keep moving at a gradually reduced speed and then, as the train ahead departs, the second train can run on into the station and stop without having been required to stop and lose time unnecessarily at a signal in approach to the station.

The signals in approach to a station, called station-timing signals, are spaced closer together with their controls overlapped to govern over several blocks, so that a train standing at a station platform is protected by

If the speed of the train is reduced so that the head end does not pass the next signal before the timing relay completes its operation, then that signal will have its extended overlap control cut off, the train-stop will be lowered to its non-tripping position and the signal will change from the red to the yellow aspect so that the train can continue without stopping.

If this train continues at the restricted speed, the next signal will have its extended control cut off by the second timing relay, and so on, thus bringing the train up closer to the station, so that as the leading train departs, the second one can pull up to the platform at approximately the same speed. Thus the capacity of the track as a whole throughout the length of the subway is increased by decreasing the speed of a following train, thereby reducing the spacing between trains in those sections where trains make regular stops.

When no train is occupying the station, the signals in approach to the station normally display the green

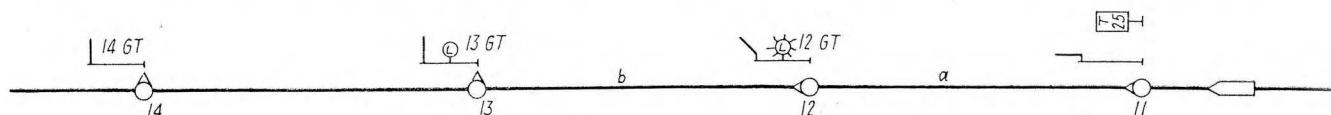


Fig. 5—Diagram illustrating grade-timing signaling

changes to green just prior to the time the head end of the train passes the signal such as 12 in Fig. 5.

### Track Occupancy Control

If, as the train was approaching signal No. 12, the lunar white marker was not lighted in combination with the yellow, this would indicate that

three or more red signals, the total distance providing safe braking distance at maximum speed. For example, in Fig. 6, the overall distance from signal 21 to signal 24 is the full block length for train-stopping distance at maximum speed.

In addition to the special overlap, the controls of these signals are arranged so that, with a train at the

aspect. Therefore, under these conditions a train approaches at normal speed.

### Time-Relays Driven by Code Transmitters

The time-element relays are all of the ratchet type, operating on 16 volts d-c., and can be set to operate for any

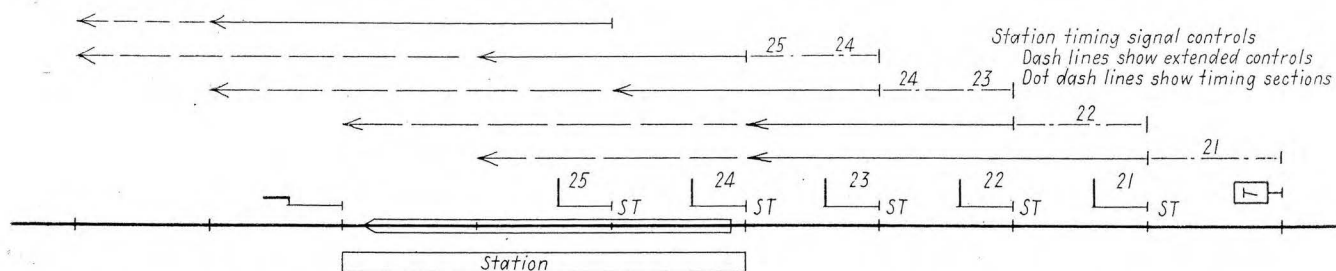


Fig. 6—Station timing signal controls, the dash lines show extended controls and the dot lines show the timing sections

signal No. 13 is displaying the red aspect because a train ahead is occupying the track, and, therefore, that signal No. 13 will not clear regardless of how slow the second train is run. Based on this information, the motorman is prepared to stop his train short of signal No. 13. With this form of control, the blocks on descending grades can be short enough so that the time-distance of trains in such blocks is about the same

station, a second train can close in under the authority of yellow aspects by reducing speed sufficiently so that the train can be stopped if necessary in the length of one of the short blocks. An illuminated "T" sign informs motormen where the special timing controls start so that they can reduce the speed of their train accordingly.

When a train enters each block, the operation of a timing relay is started.

timing from  $2\frac{1}{2}$  to 25 sec. or 10 to 120 sec.

The shorter range relay is calibrated in 2.5-second divisions, the longer range relay in 10-second divisions. Both relays are adjustable for time interval by screw thread, providing micrometer adjustment for fractions of a second.

All of the time relays in an interlocking, on a grade-time zone or in both areas in approach to a station are

driven by a circuit fed from a pendulum-type code transmitter which operates continuously from the 16-volt d-c. supply at the rate of 240 times each minute. The output of the code transmitter feeds bus wires extending throughout the limits of the station timing or grade zone. The timing-relays and the code transmitter are of the plug-in type and are the same outside dimensions as the other relays.

### Single-Rail Track Circuits

The energy for the motors on the cars is at 600 volts d-c., the positive side of which is connected to the third rail, and the negative return is connected to one of the track rails. The other track rail, called the signal rail, is cut into track circuit lengths by the use of ordinary insulated rail joints. At the feed end of a track circuit, one wire from the secondary of a track transformer is connected to the signal rail next to the insulated joint and the other wire is connected to the negative rail. At the relay end of the circuit, one wire from the track relay, which is the a-c. vane type, is connected to the signal rail next to the insulated joint, and the other wire is connected to the negative rail. The relays and transformers are protected from excessive propulsion current by means of a resistance unit and 600-volt fuses inserted in the connections to the signal rail. One advantage of using this so-called "single-rail" type of track circuit is that no impedance bonds are required, and, furthermore, the exact ends of track circuits can be fixed without cutting rails too much.

### Power Supply and Distribution

Electrical power equipment for feeding the signal system is located at each of the three interlockings and also at eight intermediate points. Each of these power sources feeds a certain territory. At each source, duplicate transformers with automatic transfer equipment in the secondary leads, supply a two-wire single-phase 110-volt signal power distribution circuit which extends to all the signal and track circuit feed locations on the given territory. Also, in each power room there is a set of rectifiers in multiple which feed a 16-volt d-c. power distribution circuit which extends on two wires to each signal to feed control circuits, as well as electro-pneumatic valves for switch machines and train-stop mechanisms.

Compressed air for operation of the electro-pneumatic switch machines and train-stop mechanisms is provided by two compressor plants, one at North Portal and the other at

Southbound train descending from the elevated structure to the subway at the North Portal plant



Thirteenth street. Each plant includes two compressors, each rated at 150 cu. ft. per minute. Each of the two tracks in the subway is in a separate tunnel and, therefore, a separate 1½-in. air pipe was required throughout the length of each of the two tunnels.

### Cable Distribution

The automatic block signal line circuits are No. 14 wire in aerial-type cables. These cables, together with the 2-conductor cables for the 110-volt a-c. and the 16-volt d-c. power, are run on messengers on brackets on the walls of the subway tunnels and along under the station platforms.

All the relays are the quick-detachable plug-in type which permits a relay to be replaced quickly without changing wire connections. These relays are housed in cases at the automatic signals. At the interlockings, the relays are on racks in instrument rooms in the towers.

### 138 Trains an Hour

Between 8 a.m. and 9 a.m. every week day, there are 69 trains scheduled northbound and the same number southbound through the North Portal interlocking. Three and sometimes four or five trains are occupying the plant limits including the approach sections. The route control system is, therefore, an important advantage in changing line-ups quickly. As a special feature to permit new routes to be set up automatically as soon as the rear of a departing train clears the release section involved, provisions have been made for the "storage" of controls. For example, a northbound train coming out of the tunnel is using the route to the northward express track via signals 16, 30 and 48, Fig. 2, and the next northbound train from the elevated track No. 3 is to be routed via crossover 3 re-

versed to follow the other train. As soon as the first train passes signal 30, the operator can "store" the control for the route from signal 12 via crossover 3 reversed by pushing buttons 12 and 28. As soon as the rear of the first train clears the sectional route release track circuit, the crossover will at once be operated to the reverse position and signal 12 will be cleared accordingly. This "storage" of control saves seconds at the right time to prevent unnecessary train stops.

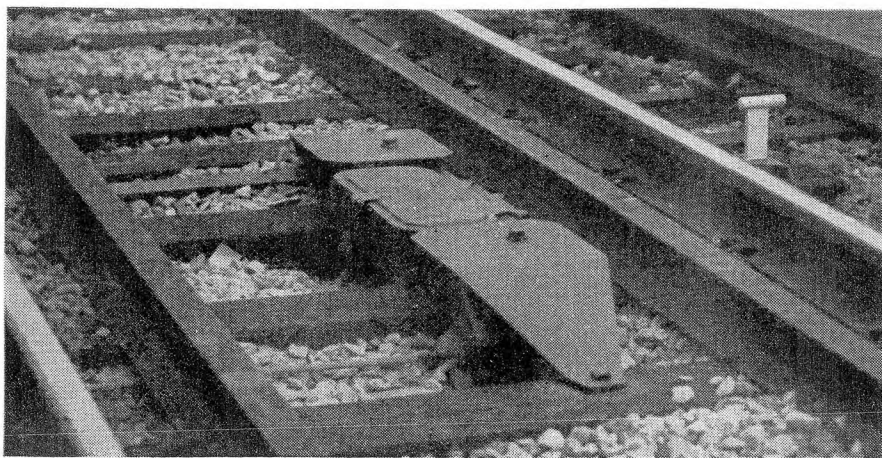
### Interlocking Machines

The interlocking machines and controls are of the "UR" Union Route type. The three plants are of the same construction and, therefore, the following explanation will be confined to the North Portal plant.

The panel of the machine is 22½ in. high and 60 in. long and is made of sheet steel treated with baked enamel having a dull black surface. The track and signal layout is reproduced in miniature on this panel, each track being represented by moulded translucent glass sections, which are fitted behind slots 3/16 in. wide cut in the steel panel. When the plant is normal, these sections of glass are not illuminated.

Each signal is represented on the diagram by a symbol. Adjacent to the symbol for each interlocked signal, and on the line representing the track, there is a push button, known as a route button.

Thus there is a push button for each signal where a route may start, these being known as route buttons. In order to line up a route, the operator pushes the button corresponding with the signal at which the approaching train is to arrive at the plant. This action is indicated by the appearance of a red light at the side of this button. Then he pushes the button at the



Train stop mechanism and trip

exit light on the line representing the track on which the train is to depart from the interlocking limits. This initiates actions which control the switches and crossovers to be operated to the positions called for to complete the route. The track sections representing the switches, which are already in the position called for, will be lighted white, whereas those representing switches to be operated will flash red until the switches are over and locked, then the indicating sections will be lighted white. Thus when the track line up is complete, the route is indicated by a continuous illuminated white line. Then the signal clears, which is indicated by the lamp at the side of the entrance route button changing from red to white.

Track sections of the diagram representing a switch are flashed white when an approach signal locking this switch indicates clear or when a train is occupying the extended locking sections of the switch.

As the train accepts the signal and passes through the plant limits, the lights in the separate sections of the track diagram change from white to red as the train occupies each of the corresponding track circuits, and after the rear of the train clears any given circuit, the light in the corresponding indicating section is extinguished, unless non-stick control is in effect, in which case the sections again show white.

Routes which are initiated by *pushing* the entrance route button and the exit route button are under "stick" control; i.e., such routes are automatically cancelled when a train accepts the signal and passes through the plant. On the other hand, if a certain route is to be used by two or more following trains, "non-stick" control can be established so that the signal will again clear for each succeeding train without any action on the part of the operator. This "non-stick" control is established by push-

ing and turning the entrance route button. In order to cancel this control, the button must be turned to normal position and pulled out momentarily.

### Through Routing

When a train is to make a move through the plant on express tracks, the route can be established by pushing the first entrance route button and the last exit route button. This is called through routing in contrast with requiring that the button for each signal on the route be pushed. For example, when making a move from the northward track in the subway to the northward express track on the elevated, the operator pushes

entrance route button 16 and then pushes exit route button 66, Fig. 2. After all the switches are properly positioned, all of the signals will clear, including 16, 30, 48. This obviates the pushing of route buttons 30 and 48, and is known as through routing. A through route can also be established by pushing entrance button 16 and exit button 68.

The interlocking signals for the normal directions of traffic each have two signal heads and a third unit at the bottom, which is a normally extinguished yellow lens. The aspects in the top head apply in general to the straight-track route, the aspects of the second head apply to the diverging routes. The display of a proceed aspect in either the top or the second head depends not only on switch position but also on non-occupancy of the tracks in the route. If all the switches have been positioned properly for a route by pushing an entrance button and an exit button, but the signal does not clear due to an occupied track section, a yellow call-on aspect can be displayed on the third "arm" of a high signal, by also pushing the call-on button corresponding with the signal. These call-on buttons are in a row above the track and signal diagram. A special feature is that when the call-on aspect is displayed, this fact is indicated by a flashing white light rather than a steady white light at the entrance route button. A call-on line up is cancelled by pulling the entrance route



The plug-in type relays can be replaced quickly and with no wire change

button. This call-on control applies also to all of the reverse-traffic dwarf signals.

### Signal Take-Away

If a route has been established and the signal cleared, but this route is to be taken away without having been used by a train, this result is accomplished by pulling the entrance route button. Then the white light at the button, as well as the continuous white line of light on the track diagram, are extinguished. However, if a train is approaching the signal when the route is thus cancelled, the approach locking takes effect, and the continuous white line of light on the diagram persists for a period of approximately 20 seconds, thus indicating that the route is locked for that period of time, and, therefore, no conflicting route can be established.

Time locking rather than approach locking is provided for all dwarf signals. If a route button controlling a dwarf is pulled, the continuous white line of light on the control panel will persist for approximately 20 seconds; i.e., until the time-element relay operates to release the locking.

A special feature of this interlocking is that the approach signals are semi-automatic, this being arranged so that the towerman can stop a train at such a signal. The signals 4, 10, 34, 36, 38, 56 and 62 can each be cleared by its respective control button without the use of an exit button. If such a button is turned when in the pushed position, the control is non-stick so that the signal will again clear after a train proceeds beyond the track circuit control limits.

When a switch is being inspected or adjusted it can be controlled individually by a separate lever rather than by the route control system. For this reason, individual control levers for the switches and signals are provided on the panel below the track diagram. A special feature of these switch levers is that they are of the three-position type, normally they stand on center in which position they are ineffective in controlling the switch, and, furthermore, these levers must be in the center position in order for the route control to be used. A lever is operated to the left to control its switch to the normal position or to the right to control it to the reverse position. In order for this lever control to be effective, all route controls affecting the switch must have been cancelled, and all home signals leading to routes over the switch must, of course, be in the Stop position, and its detector locking sections free.

When the work on the switch has been completed, the switch can be

returned to the control of the route system by placing the lever in the center position.

If a track circuit failure causes the electric locking to be effective in preventing the operation of a switch by ordinary means of control, a special form of emergency release and control may be used. All home signals, dwarf signals and approach signals governing routes including the said switch are placed in the Stop position. Next the auxiliary switch control lever for that particular switch is thrown to either the normal or the reverse position depending on which position of that switch is desired. Then the operator breaks the seal on the emergency release button directly under the said auxiliary switch lever by pushing in the button, after which the button is pulled out and held until the switch operates to the position to correspond with the position of the auxiliary lever, which will be indicated on the panel. Pulling the lever, after being pushed, starts a time-element release which is adjusted to operate in about 30 seconds, after which the switch will operate.

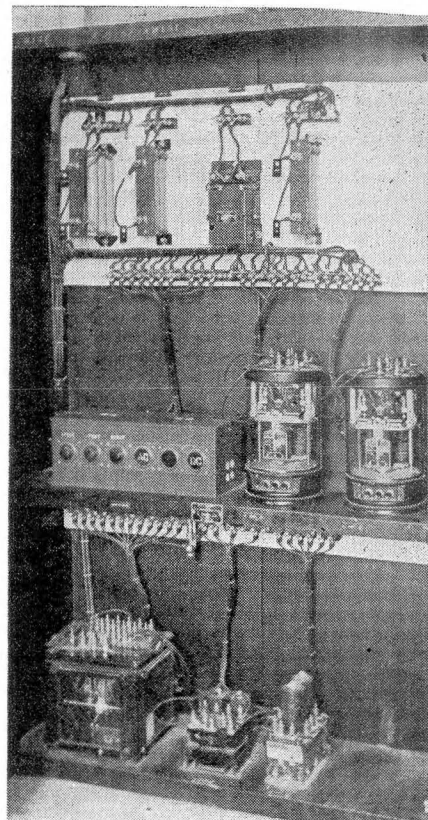
After the switch lever has been placed on center, the route control buttons can be used to establish the remainder of the track line up and clear the signal, which would be the call-on signal if a track circuit is out of service.

### Control of Hand-Throw Crossovers

As previously mentioned, a set of diamond crossovers is located south of the Grand Avenue station and another set is located south of North Avenue station. The switches of these crossovers are each operated by a Union Switch & Signal Company Model T21 hand-operated switch-and-lock mechanism, equipped with an electric lock which locks the switch operating lever in the normal position.

All four of the electric locks at a diamond crossover layout are controlled by one clockwork time release, which is mounted in a case with lamp indicators. When the door of this case is opened, a switch is closed to feed energy to the indication lamps. If no train is approaching within certain approach limits on each track, the corresponding indicator lamps are lighted. The clockwork release is turned by hand to release it. This action places the signals in each direction to their most restrictive aspect. After the release runs down, which requires 1 minute, the electric locks on the switches are released. The key for the switch padlocks is sealed in the time release case.

The signal control circuits check through the front contacts of a special



Ground detector relays and lamps

crossover track circuit, through normally-closed contacts that check the normal position of the switch, the locked position of the lock plunger, and the normal position of the hasp controller, so that if the switch pedlock is removed, the control circuits are open. The clockwork release must be turned by hand to return it to the wound position in order that the door of the case may be closed.

Chicago's first subway was designed and constructed under the supervision of Philip Harrington, Commissioner of the Department of Subways and Super-highways. The automatic signaling and interlocking was planned and installed under the direction of C. W. Post, Electrical Engineer, assisted on signaling matters by Walter W. Wenzholz of his office, as well as by R. N. Wade, Engineer Maintenance of Way and C. A. Butts, Assistant Signal Engineer, of the Chicago Rapid Transit Company, which company operates the subways. The Federal government shared the cost of the project and otherwise co-operated with the city through a special Subway Commission of which Joshua D'Esposito was P.W.A. project engineer. The major items of signal and interlocking equipment as well as circuit plans, were furnished by the Union Switch & Signal Company, and the wire and cable in connection with the signaling was furnished by the Kerite Insulated Wire & Cable Company.