Chicago's Newest Subway Has Automatic Block Signaling and Train Stop

Rapid transit trains on the Milwaukee avenue subway running on a two and one-half minute headway are protected by automatic train stops and automatic block signaling

CHICAGO'S Milwaukee-Dearborn-Congress subway is equipped with automatic train stop devices and automatic block signaling as well as station and grade time control which provides an even flow of traffic over the line. This subway is Route No. 2 of the Chicago Subways and extends for 3.99 miles from its connection with the Logan Square elevated near Damen avenue to the Loop. From near Damen avenue, the subway runs southeast under Milwaukee avenue to Lake street, east under Lake to Dearborn, south under Dearborn to Congress and west under Congress to its terminal near La Salle street. This subway is saving rapid transit riders an average of 15 minutes in going from Logan Square to downtown.

Although construction of the subway was started before the war, the emergency's shortages of materials and men halted the work. After the war, work was resumed and the subway was opened to operation in February, 1951.

Traffic

During rush hours, Monday through Friday (7 a.m. to 9 a.m. and from 4 p.m. to 6 p.m.), six-car trains run on a two and one-half minute headway. At other times during week days, four-car trains run on a four minute headway. On Sundays, holidays and evening hours two-car trains run on a seven-minute headway. Owl trains, from 1 a.m. to 6 a.m., are two-car trains, running every 30 minutes. All trains stop at all stations. The signal system however is designed for a 1½ minute headway to take care of traffic when in the future connections are made with elevated lines from the west at Congress and Lake streets.

Track Layout

The Milwaukee avenue subway (Route No. 2) is double track all the way from Congress street station to the end of the elevated at Logan Square. There is a diamond crossover at the end of the station platform at Congress street station with four electro-pneumatic switch machines. These switches and their associated signals are controlled by a Union "UR" route interlocking machine located in a tower at the east end of the station platform.

There are two emergency crossovers on the line located at Hubbard

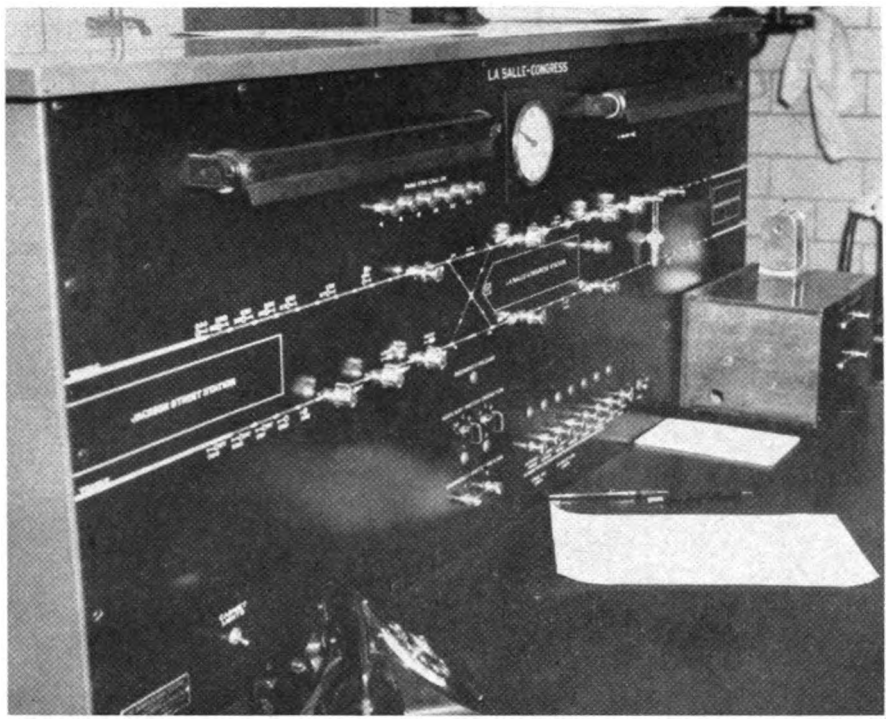
street in the subway and on the elevated line just south of Damen avenue. Switches for these crossovers are hand-thrown, using a switch-and-lock mechanism equipped with electric locks.

Automatic Block Signaling

Automatic block signaling is used throughout the subway and on the elevated to Damen avenue. Signaling is arranged for one direction running only, and trains normally use right-hand running. The signals are the vertical color-light type, with the conventional red, yellow and green aspects.

Interlocking home signals have two "heads" each consisting of three lights in a vertical row. Below each "head" is an illumination number plate bearing an X and the lever number. A letter "A" is placed under the top "head" and a letter "B" under the bottom "head." For example (see Fig 4) signal 22 has two illuminated number plates, the upper one reads X22A and the lower one X22B.

On home signals in the approach to diverging routes, the upper signal "head" controls the through route, and the second "head" controls the diverging route. Approach signals, located within the approach locking limits, are also lever controlled. All approach, block and home signals are at the right of the track governed. Repeater signals are in use on curves, being placed on the left of the track they govern so that motormen may be able to see signals at all times.



Interlocking control machine is "UR" route type with a line-of-light track layout

Aspects

A red aspect indicates Stop and proceed prepared to stop within a train length, and requires that the motorman stop his train and release the automatic train-stop trip. The motormen are not to key-by a stop signal unless they have waited about one-half minute and are then reasonably satisfied that there is no train ahead. Yellow indicates proceed with caution prepared to stop at the next signal. And green indicates proceed. A lunar white marker is used on the grade-time signals. This light indicates that the grade-time control is in operation, as will be explained later in the article. A red-over-red-over-yellow aspect is a call-on, used only on the home signals at the Congress street interlocking as will be later described.

Automatic Train Stop

Automatic trip type train-stop devices are installed at all signals except repeater signals. These trips are "T" shaped devices which are at track level and are on the side of the left running rail. They are depressed one-half inch below the top of the rail when the signals, with which they are associated, display either a green or yellow aspect. When the signal is red, the trip projects approximately 3⅞ inches above the top of the rail. If a train is run past a red signal, the trip strikes a lever on the left side of the leading truck of the car whch causes the brakes to be applied in emergency.

In normal operation, for example, a train approaches a red signal. The motorman stops the train with the front of it just short of the signal, so that he may reach out of the cab window and operate a trip release lever on a bracket projecting from the signal mast toward the approaching train. When the motorman operates this release the trip is depressed. The train can then proceed without having the brakes ap-

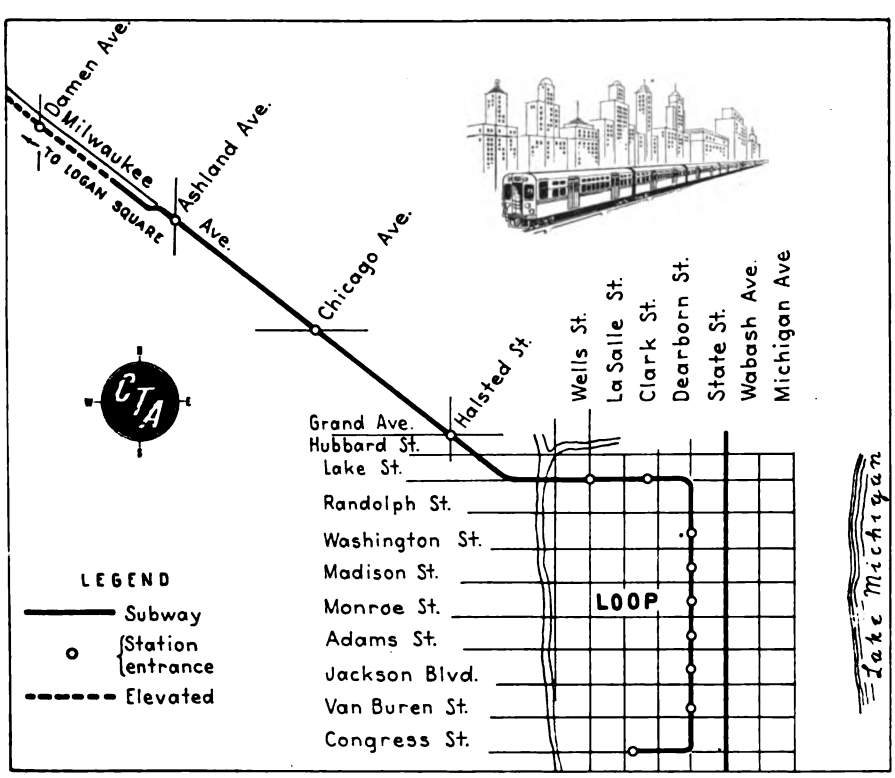
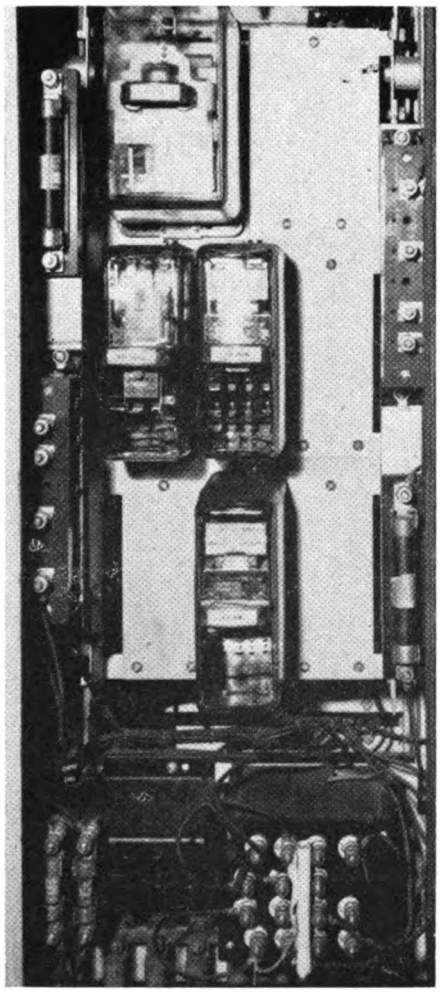


Fig. 1 Map showing route No. 2 of the Chicago Subways

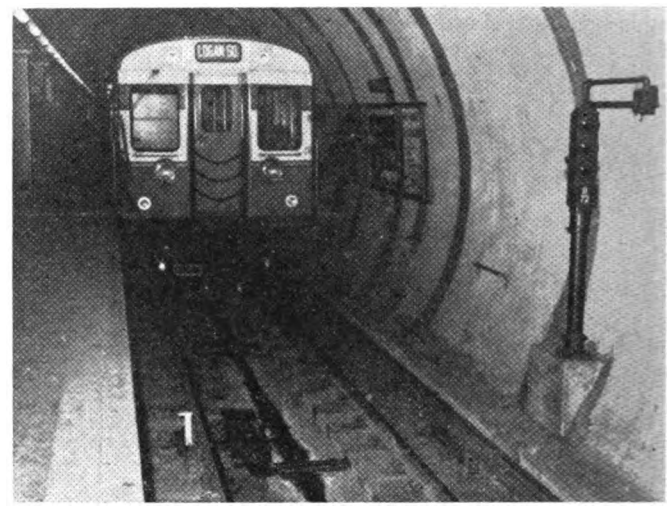


Front view of a track-side relay case

plied by the operation of the train-stop trip. At a home signal the call-on aspect must be displayed before the above operation is effective.

Track Capacity

The minimum block length is the distance necessary to stop a train at its maximum attained speed with an emergency application of the brakes plus a factor of safety. In normal automatic block territory signal controls have a one block overlap due to the use of train stops. Referring to Figure 2 a train in block sections b and c would not have full protection from the train stop at signal 6. Consequently the stop at signal 5 must also be in the tripping position. Trains then are kept two blocks apart when running under caution signals. This does not affect track capacity in free running territory where blocks are often longer than the minimum length. However on descending grades the block lengths at maximum speed would be prohibitive, also normal block lengths keep trains too far apart at station stops. In both of these cases trains are closed in to obtain greater track capacity by restricting their speed. This can be safely done by means of time controls.



Rear view of a train standing in the station with the signal showing a red aspect and the train-stop trip in the raised position

Grade Time Control

Maximum grades are three per cent where the subway goes under the Chicago river and where it joins the elevated structure. Elsewhere the tracks are almost level (as they are in stations) with a variation in grade, for drainage purposes, of only one-half of one per cent, or less.

Referring to Figure 2 the grade time control operates in this manner; consider signal 7 located at the top and signal 12 at the bottom of a descending grade with the intervening signals spaced on short blocks or rather sections of a block. The control for signal 8 extends to signal 12 where track sections e, f and g provide the length for braking a train at restricted speed when section h is occupied as shown on the diagram by a solid line. The dotted portion of this line represents two timing sections c and d. The remaining grade time signals 9 to 12 have the same controls. An illuminated sign at the beginning of the timing section for signal 8 informs the motorman the restricted speed at which he must run to allow sufficient time for time element relays to clear the signals. The grade time signals normally indicate red with the train stops in the tripping position to enforce the speed restriction.

Signal 7 has no time control, is not a grade time signal and the sections d, e and f within its control limits will vary in length depending on the maximum speed an approaching train can attain.

Signals 7 to 11 inclusive each have a lunar-white marker which may be displayed only with its respective signal showing a caution indication. This marker informs the motorman that, if displayed, the next signal is red because of time control only and if dark, that the next signal is red because a train is within its control limits.

A train in track section c travel-

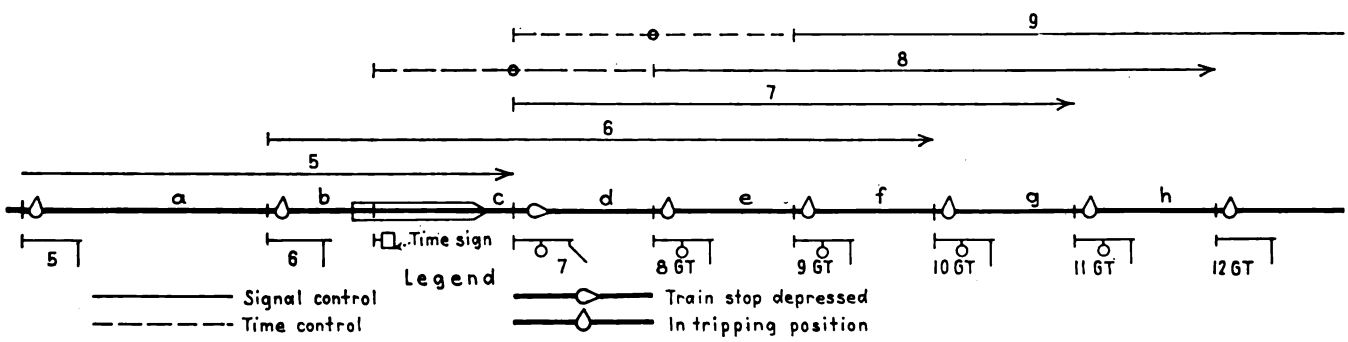


Fig. 2 Diagram showing grade time control signals

ing at the prescribed speed will allow sufficient time to clear signal 8 to a caution indication, permitting signal 7 to change to green immediately in front of the train. The remaining grade time signals will clear in a like manner as the train proceeds down the incline at or under the permissible speed. The motorman may elect to take a longer time to brake his train and accept signal 7 at the caution indication. He then will have another opportunity to consume the required time in section d, then both signals 8 and 9 will clear to caution whereupon signal 8 will change to green.

Front view of a subway train standing in one of the stations

Station Time Control

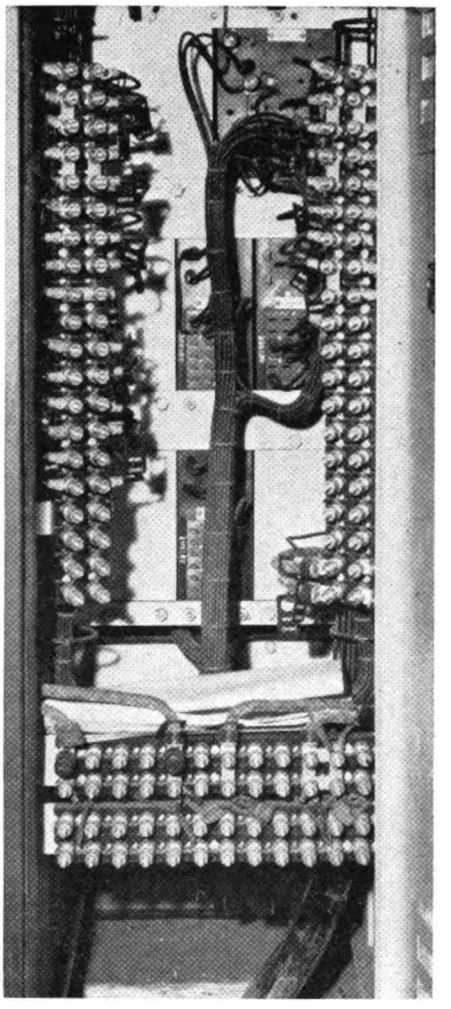
There is a continuous center platform the entire length of that portion of the subway under Dearborn street, having three station stops for each track. Considerable time is consumed in loading or unloading in this downtown area, consequently trains would be delayed during rush hours were it not for station timing which keeps trains running closely together at restricted speed.

Referring to Figure 3 signals 21 to 25 inclusive are station time signals with their controls showing a dotted timing track section to the rear, a solid line for the station time control and an extended dotted portion for the control without station timing. An illuminated sign informs the motorman where time control begins. With a train standing at the station a following train running at its maximum attained speed would be tripped at signal 21 and be stopped short of signal 23. However if the train travels at or under the permissible speed in track section a, then a time element relay will operate to cut off the extended control of signal 21 and permit it to clear to caution. Then as the train at the station moves ahead and the second train runs slowly enough in section b to cut off the extended control for signal 22 which permits it to clear as soon as the first train is off of section d. In this manner one train can closely follow another into a station area. Speed restriction is enforced by the train ahead setting the signals to the stop indication. With no train ahead, as in non-rush hours, the extended controls are effective and the signal circuits are so designed that the timing relays do not operate.

Plug-In Relays

All relays are the plug-in type. No polar relays are used. The track relays are the a.c. vane type operating on 60 cycles. Time-element relays are the Union PT-55, which are the ratchet type with adjustments of time from 2.5 sec. to 25 sec. These relays operate on 16 volts d.c. from a coding unit which sends out a d.c. code of 240 cycles per minute.

Relays are on racks in relay rooms at the stations, and on the line in the tube, relays are in cases placed near the signal and equipment with which they are associated.



Rear view of a track-side relay case

Track Circuits

The Milwaukee avenue subway trains operate on 600 volts d.c. using a third rail as positive and one of the track rails as the negative return. The other track rail is used as the signal rail for a.c. track circuits. Insulated joints are used in only the signal rail. At the feed end of a track circuit section, one wire from the secondary of a track transformer is connected to the signal rail and the other to the negative track rail. At the relay end of the track circuit, one side of the a.c. vane type relay

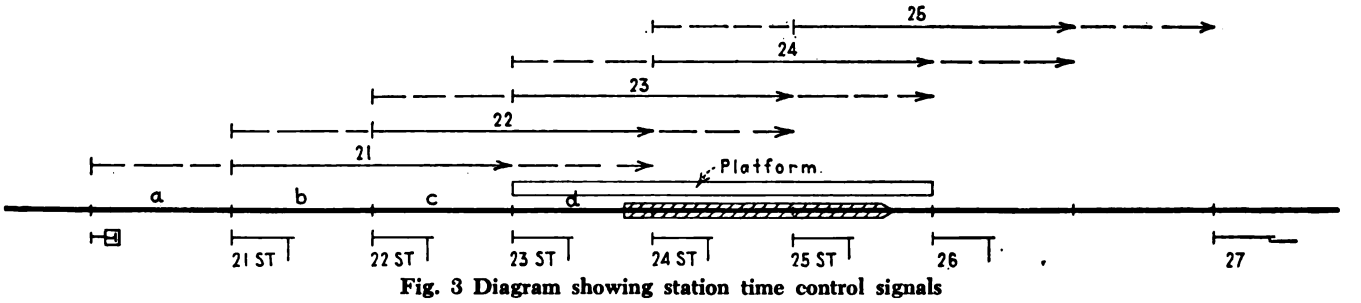


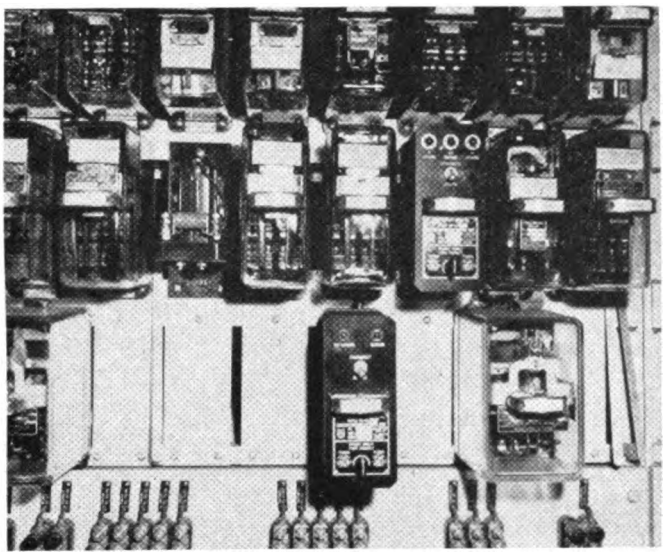
Fig. 3 Diagram showing station time control signals

is connected to the signal rail and the other to the negative return rail. Advantages of the single-rail a.c. type track circuit are that no impedance bonds are needed and the track circuits can end at a rail end, thus eliminating unnecessary cutting of the rail.

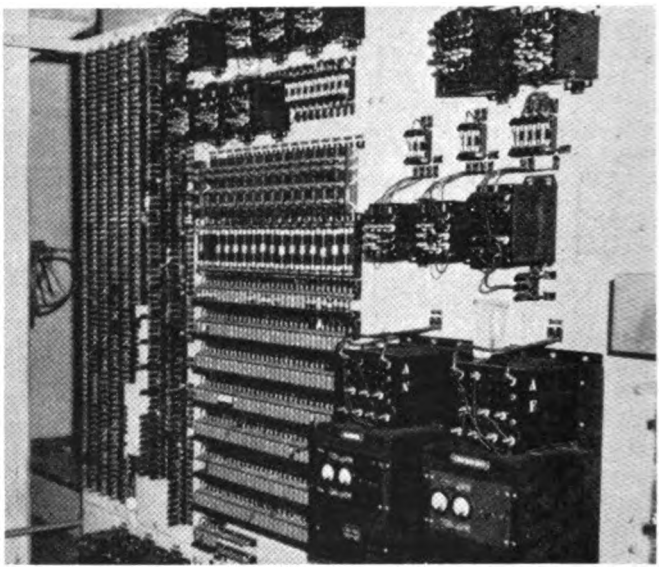
Power Supply and Distribution

Power for the signal system is fed from several points along the line from commercial sources. At the interlocking tower at Congress street and at certain other points, there is a power and relay room where transformers are connected to normal and reserve commercial sources by means of a transfer switch. This automatic transfer switch will cut in the reserve commercial source if the main source of supply should fail, and will automatically return to the main source as soon as the failure has been corrected. Overload protection equipment is also installed on the power lines. The a.c. power at 110 volts single-phase is distributed locally through each subway tube on a two-wire line of No. 6 wire. Signal lighting and track circuit operation is a.c. Pairs of rectifiers paralleled on the output side are used to convert the 110-volt a.c. to 16-volt d.c. for the signal control circuits including the controls for the electro-pneumatic valves for the switch and trip mechanisms. This 16-volt d.c. is distributed through No. 6 wire in aerial type two-conductor cable run with the two-conductor 110-volt a.c. power supply line on messenger wires on the walls of the tunnels and under the station platforms. Also included in each power room are automatic ground detectors for each d.c. and each a.c. power feed. Operation of the transfer switches and ground detectors is indicated on the control machine at La Salle-Congress interlocking.

Compressed air for the operation of the switches and train stop mechanisms is provided by a compressor plant at Damen avenue station. Also there are two cross-connections with the air lines of the State street subway, so that compressed air is always available. A 1½ in. air line is in each subway tube to provide air for equipment on each track. Compressors are rated at 150 cu. ft. per minute and there is a low pressure air alarm at the Congress street interlocking tower to indicate when the air pressure falls below 85 per cent of normal.



Plug-in relays and automatic ground detector (third unit from right in second row of relays) mounted above current limiting resistors on a panel



Terminal board in one of the relay rooms with current limiting resistors and pair of rectifiers (lower right in the picture)

Current Limiting Resistors In Control Circuits

There are 100-ohm resistors in series with 1600-ohm relays (PN-50 or PN-50B), and 30-ohm resistors in series with the LP-58 relays. Some 20-ohm resistors are used in other operating circuits. If a short circuit occurs in the control circuits, it will cause the circuit to be inoperative, but will not blow the power supply fuse. This will prevent a serious tie-up in traffic on the subway. Experience has shown that current limiting resistors are feasible. The short is capable of being found by the maintainer without damage to the signal control circuit or equipment, and, at the same time, power to other controls is not cut off.

Interlocking Machine

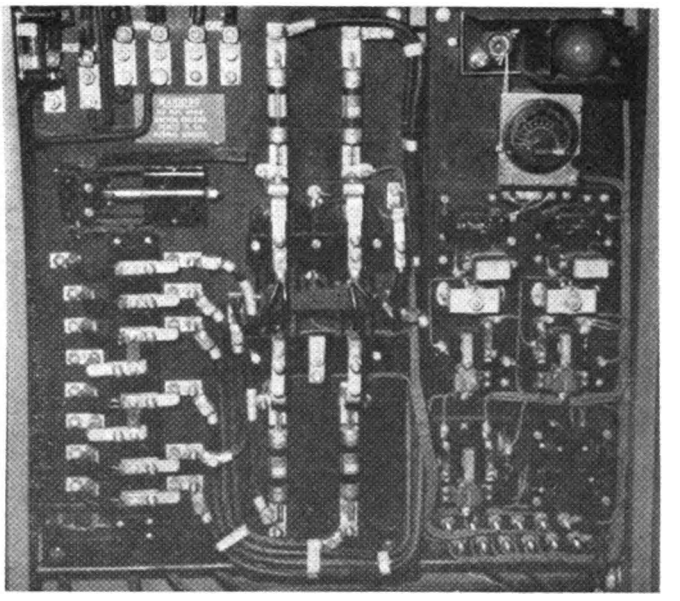
The interlocking machine at the Congress street station is the "UR" route type, with a control machine containing a line-of-light track layout, and knobs which can be pushed or turned for selection of routes through the interlocking, and levers for auxiliary operation of switches. The control machine is also equipped with a row of red indicating lights warning of low air pressure, interlocking power interruption, automatic power interruption, and grounds on interlocking ground detector and automatic signal ground detector. When one of these units operates or power fails, the corresponding red light is illuminated and a bell rings. A pushbutton under the light will stop the ringing bell. There is also a maintainer's call button on the panel.

To initiate a route, the operator pushes a knob on the track diagram at the point representing the signal where the train is to enter the route. A red light will appear in the signal indication light at that knob and short sections of white light will appear on the track diagram at each available exit. The operator then pushes the knob on the track diagram representing the point at which the train is to leave the desired route and then, if conditions permit, the switches will be positioned to line up this route after which a continuous white line of light will be displayed on the track diagram from the entrance to the exit points of the route. Before each switch has reached its proper position, a flashing red light appears in the diagonal section of the crossover

including that switch. Normally these switches take two or three seconds to operate but should a switch be obstructed or for any reason fail to complete the desired movement, this continuous flashing red light would call the operator's attention to that fact. After the route has lined up, if conditions permit, the trip at the entrance to the route is cleared and the signal at the entrance to the route will display the proper proceed aspect, after which the light at the entrance knob on the track diagram will change from red to white.

As a train enters the route, the track circuits occupied by the train show up as red, and when the train leaves a track circuit, the red is extinguished. The route is automatically cancelled as the train proceeds through the interlocking. However, if the operator wishes to keep a route for a following train he may push and turn the entrance knob thus establishing a route that will not cancel with the passage of the train. To cancel this route, the operator must turn and then pull out the entrance knob momentarily.

On the desk portion of the control machine is a box containing two buttons with associated indicating lamps that are used to illuminate an arrow on the platform sign for the next train out of the station. When the operator pushes one of these buttons, an arrow on a sign over the platform is illuminated, which points in the direction of the train next leaving the station. An amber lamp lights on the control panel to indicate that the arrow is lighted. Next the operator lines up the route for the train by pushing knobs for routes 22 to 24 or 8 to 24, depending upon which track the train is standing. When the route is established it shows as a white line on the control panel, and the green starting lights on the platform are illuminated. Also a single-stroke bell is sounded to indicate to the train crew that the route is established and the train may leave. The starting lights are located on brackets suspended from the roof over the platform. There are three of them, one opposite the place taken by the conductor of a train between the first and second cars and between the third and fourth cars. A third light is located at the east end of the platform in view of the motorman. However, the usual procedure in starting a train is for the conductor to give the motorman two short buzzes on the train communicating system after the doors are closed. If the train starting lights are illuminated and signal 22 or 8 is clear, the motorman starts the train. The starting lights will not illuminate unless the route for leaving the station has been established by the tower operator, and the next train arrow has been displayed for that side. The arrow is extinguished when the starting lights are displayed and the starting lights are extinguished when the train leaves.



Transfer switch automatically cuts in reserve commercial source of power if main power supply fails

To set up reverse routes on the machine, such as moves through signals 24 to 22, 24 to 8, 22 to 6, and 8 to 6, the operator must hold the entrance button in, while he pushes the exit button. Thus it is not likely that the operator will inadvertently initiate a reverse route when setting up a normal route. On a small panel, such as this one, the operator has no difficulty in reaching both ends of the control panel in order to establish a reverse route.

Locking

The interlocking is provided with sectional route release locking as well as approach locking and time locking. Approach locking of a signal releases: if the signal is restored to stop and the train-stop device at the signal is in the tripping position, and no train is between the approach limits and the home signal; if the train is on the releasing track section; or if the automatic time-element relay (set to operate at 20 seconds) has picked up.

To restore a route with a train in the approach circuit the signal must be set to give a stop aspect then an automatic release will operate for 20 seconds to unlock the route. An auxiliary switch lever for each crossover if placed in the normal or reversed position will cause the switches to move to a corresponding position if free to do so because of electric locking. If locked a release button can be pushed and then pulled where upon a time release relay will operate for 20 seconds to release the switch locking. The switch machines are restored to route control by placing the auxiliary lever in its central position.

All interlocked home signals have a call-on aspect which is red-over-red-over yellow. The yellow is normally dark, and can only be illuminated by the operation of the call-on button by the tower operator after the route has been lined up as previ-

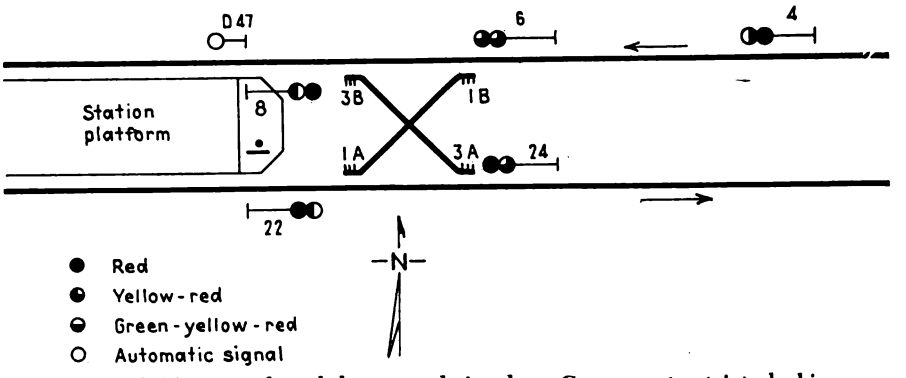
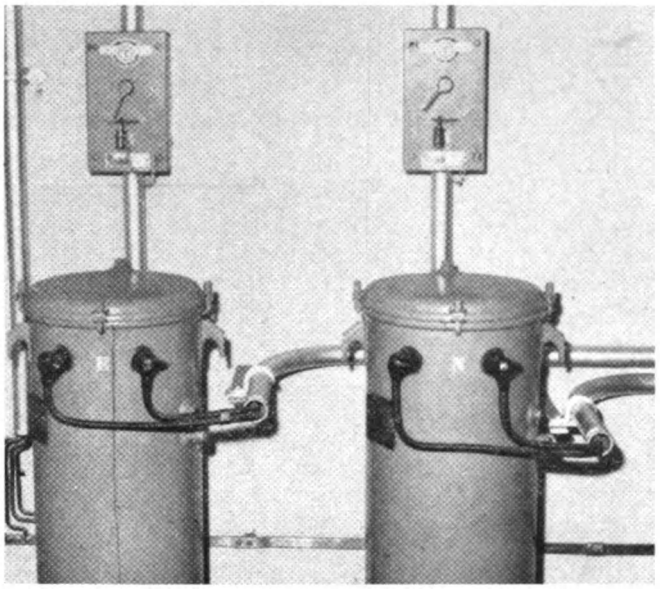
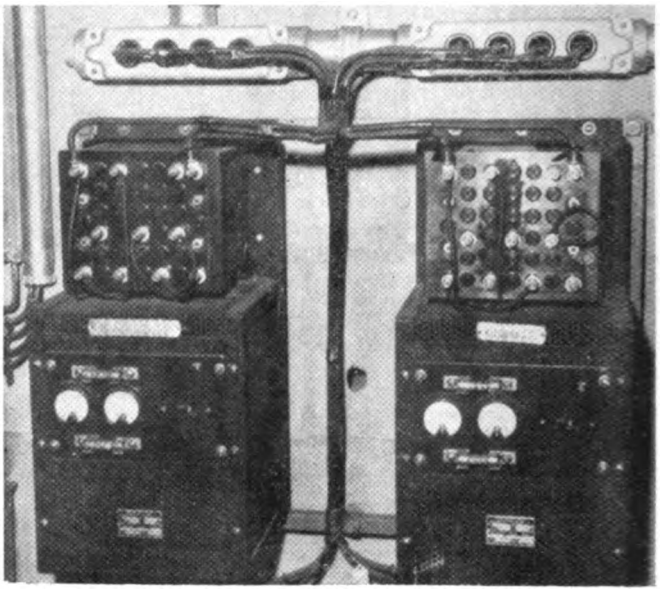


Fig. 4 Diagram of track layout and signals at Congress street interlocking

ously described. Hence any train approaching a home signal at the interlocking, such signal showing a red-over-red aspect, the motorman is not able to manually release the trip mechanism, thereby allowing the train to proceed without having the brakes set. In such an instance the motorman stops just short of the home signal and waits. When the towerman pushes the call-on button, the home signal shows red-over-red-over-yellow. Now the motorman reaches out the cab window and manually operates the trip release, thus clearing the tripping arm and the train may proceed. This operation is usually used when switching moves are taking place in the station or in case of track circuit failure. Thus an absolute stop is provided which prevents a train from entering the station area if the operator wants it held in the approach limits.



These transformers supply single-phase 110 volts a.c. from commercial sources



These rectifiers supply 16-volt d.c. for control circuits of signals and switches

Route Storage

Although the control machine does not have route storage for general moves there is one condition when it will store a route. With a train standing by the station platform on the north track, Fig. 4, west of signal D47, a route cannot be lined up for a southbound train to run straight into the station. Assuming that crossover 1 is reversed, and for some reason the operator wants a southbound train to run straight into the station past signal D47, he may set up the route by pushing buttons 6 and 8. The route, however, will not be established because safe braking distance would not be available from signal 6 to the train already west of signal D47. But this route will show as flashing white on the control panel. When the train in the station moves down into the storage area beyond the platform, crossover 1 returns to normal, signals 6 and D47 will clear, allowing the southbound train into the station.

Although signal D47 is at the entrance to the platform area, its control has been modified so that it is normally red.

If a train is routed past signal 6 toward D47, and the track beyond D47 is unoccupied, the signal will clear allowing a train into the station. This was done so that a motorman, routed by signal 6 over crossover 1 reversed, would not see a proceed aspect on D47, and also if a train ran past signal 6 at stop, the motorman would not see a proceed aspect on D47.

Hand-Throw Switches

The hand-throw switches located at Hubbard street and Damen avenue operate on a hand-throw switch-and-lock-mechanism. An electric lock on the mechanism locks each switch in the normal position only. One clockwork time release controls the electric locks on all four switches, and it is housed in a case with indicating lamps. When the door of the case is open, the lamps are lighted if the corresponding approach sections of the track are unoccupied, there being one lamp for the north track and one for the south track. A handle on the clockwork release mechanism is turned which makes the signals on approach to the crossover display a stop aspect. After the release has run down (one minute) the electric locks on all the switches are unlocked and a padlock on each switch can be unlocked and the switch moved.

Unlocked switches, removal of a switch padlock, or occupancy of the separate crossover track circuits will set the approach signals at the stop aspect. The padlock key is in the case so that the switches will not be unlocked or moved without the case open, hence the release mechanism will have performed its operation. To close the door of the case, the release lever must be returned to its normal position, which winds up the clockwork mechanism. There is also a special emergency release key that is under seal to be used to unlock the switches without operation of the time release locking. The signals are not set to Stop or the timing started until the time release lever is operated.

Route No. 2 of the Chicago subways was designed and constructed under the supervision of V. E. Gunlock, Commissioner and Dick Van Gorp, Chief Engineer of the Department of Subways and Superhighways. Automatic signaling and interlocking was designed and installed under the direction of C. W. Post, Electrical Engineer, assisted by Walter W. Wenholz of his office, as well as by C. A. Butts, Signal Engineer of the Chicago Transit Authority. All signaling equipment was furnished by the Union Switch & Signal Division of the Westinghouse Air Brake Company, and the wire and cable in connection with the signaling was furnished by The Kerite Company.