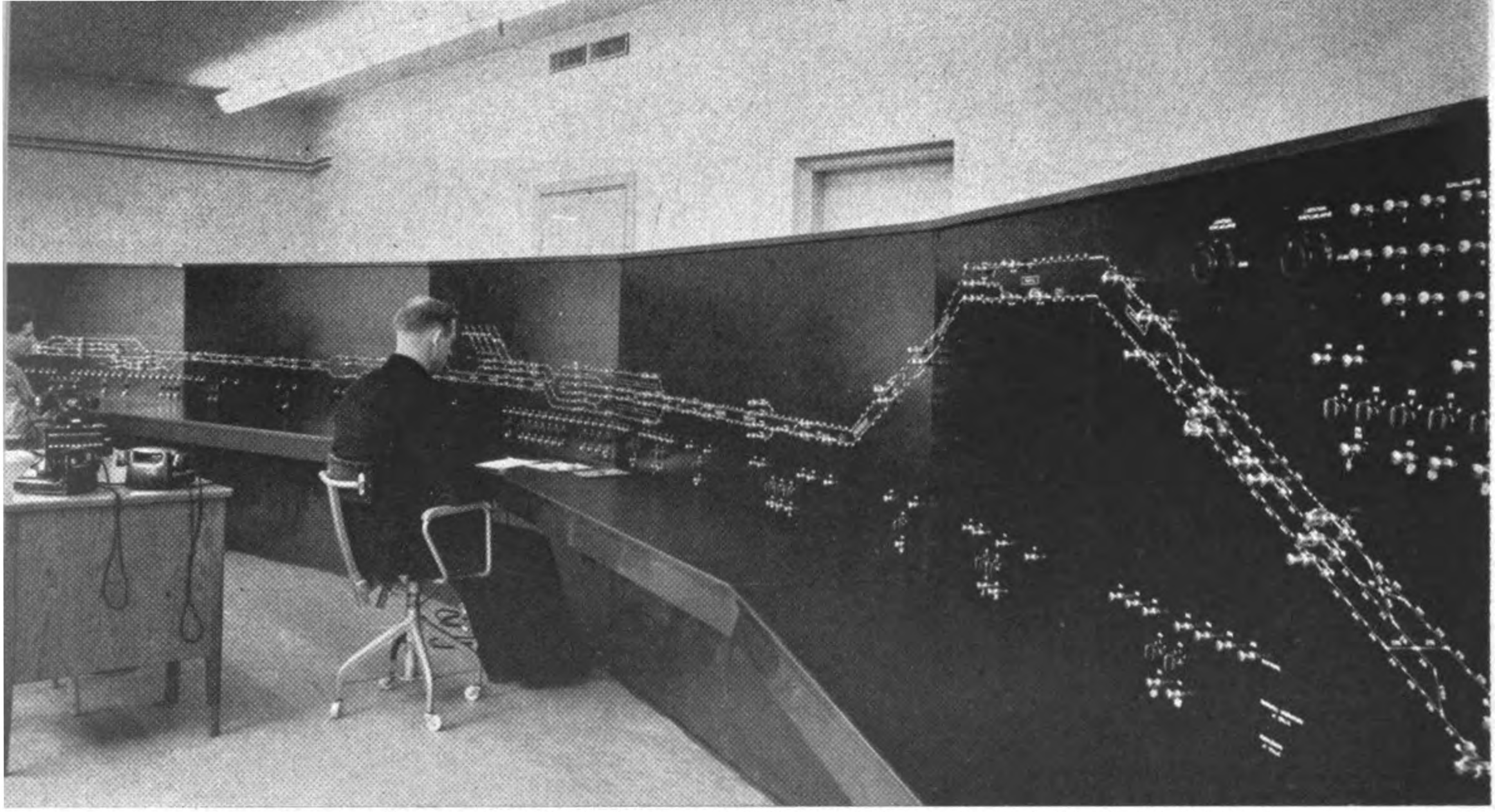


The control machine in the tower at Alvik is 30 ft. long and controls 10 mi. of double track

Modern Signaling in New Subways In Stockholm Sweden

Three-aspect continuous coded cab signaling; route interlocking controls 10 miles of double track; improved type of electronic train identification system

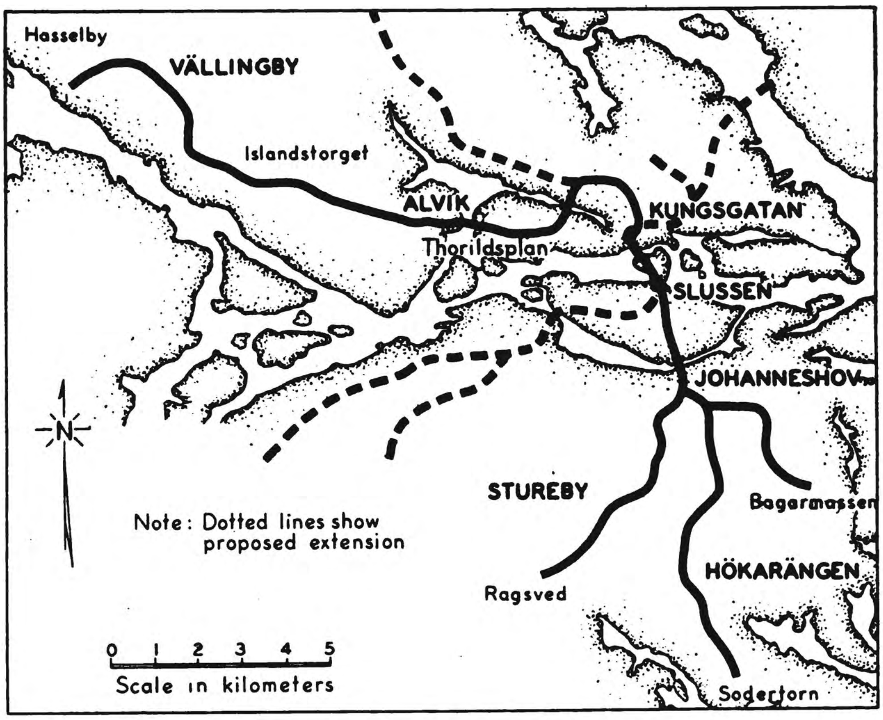
By Ingmar Boberg
Signal Engineer
Stockholm Sparvagar
Stockholm, Sweden

STOCKHOLM, the capital of Sweden, celebrates its 700th anniversary this year. A great part of this city is built on islands, connected with a number of bridges, which, with the narrow streets, have created traffic bottle necks with increasing difficulties for surface transportation. A rapidly increasing population, and an even more rapidly increasing number of private cars, have accentuated the difficulties. The population of Greater Stockholm is now approximately 1 million, and is expected to increase to 1.3 million within 20 to 25 years. At the end of the twenties, a traffic committee made an extensive study of a subway system, and they found that the proposed subway should connect the western and southern suburbs. A one-mile, double-track tunnel was built in the north-south direction in the southern downtown district. The tunnel was then to be used for 17 years for taking the street cars from two southern suburban lines into a terminal station (Slussen) at the north end of this downtown district.

Further studies on a subway system were made in the thirties, and in 1941 the city counsel agreed, in general, upon a track layout, and also decided that the street car tunnel should be extended north to the main shopping and administration districts of the city, before the western subway system should be built. The subway was to be made for a maximum of six-car trains with a total length of approximately 340 ft. No construction work could, however, been done during the war.

Because of the increase in the population, it became necessary to change the plans for the subway system in several respects. The most important decision was that two double tracks should be built in the downtown districts in order to make it possible, in the future, to connect the south-west suburbs with the north-east suburbs in a second subway system. Another important change was that the subway should be made for a maximum of eight-car trains with a total length of approximately 460 ft.

The street car tunnel was converted into a subway connecting with a new suburban line in the fall of 1950. (Slussen-Hokaragen). This system had about five miles of double track. In the summer of 1951, a branch line (Johanneshov-Stureby) of approximately two miles was completed. In October, 1952, the western section of the subway system (Kungsgatan-Vallingby), approximately ten miles of double track, was placed in service. This line extends into the main shopping center (Kungsgatan). The connections of the western and



Stockholm's first subway system. The western section, Vallingby-Kungsgatan, and the southern section, Slussen-Hokarangen-Stureby, are already being used. Connections between the two sections, Kungsgatan-Slussen, and extensions further west and south are now being built.

southern sections (Kungsgatan-Slussen) should be completed in 1958. Further extensions west and south with branch lines are planned.

Present Subway System

Of the present subway system, a total of 16 mi., approximately 20 per cent, is in tunnel, and the rest on the surface, but everywhere on its own right-of-way. The construction of the tunnel body has been made by the city construction department, while all equipment has been installed by Stockholm Tramways (Aktiebolaget Stockholms Sparvägar), which is a city owned corporation, operating subways, street car lines, and bus lines.

The propulsion voltage is 650 volts d. c. which is generated from mercury rectifiers in substations approximately one mile apart. A third rail is used. The stations are 475 ft. long and 15 to 25 ft. wide. Platforms are between the tracks. Stations have loudspeakers which can be controlled locally and also remotely from a traffic dispatcher's office.

The cars, which are 57 ft. long and 9 ft. wide, have a capacity of 50 sitting, and approximately 100 standing, passengers. All cars are motor cars, having one motor on each axle. The brake equipment is Westinghouse Air Brake Company SMEE equipment. The maximum speed is approximately 43 mph, the acceleration is 2.2 miles per hour per second, and the service and emergency deceleration about 2.5 mphps. The cars have a loudspeaker system with a microphone in the motorman's cab and loudspeakers in the cars. The loudspeaker system can also be used for two-way communication between the motorman and the guard in a train without the passengers hearing the conversation.

At present the peak hour headway on the western section is four minutes, and the maximum train length six cars. On the southern section, the peak hour headway is five minutes on each branch line, i. e. 2.5 minutes in the tunnel, with a maximum train length of four cars. Each train has a crew of two people, one motorman and one guard, who operates the doors.

When the signal system for the subway was designed, we had to start from the following premises: Headway, 80 sec.; Station stops, 30 sec.; Maximum speed, 43 mph (50 kmph) Acceleration, 2.2 mps; Deceleration, 2.5 mps; Maximum train length, 460 ft.; Train control.

Signal systems were studied in the USA (New York, Chicago, Philadelphia, Boston, and San Francisco), in England, and France in 1946-47. Two main decisions had to be made: 1.) Cab signals with continuous speed control or wayside signals with intermittent train control; 2.) Few or several signal towers, i. e. centralized or decentralized traffic control.

Cab Signaling Advantages

We considered the well-known advantages of cab signalling and continuous speed control—that the signal is visible for the motorman at all times and irrespective of weather conditions; that the train speed is controlled at all times; that several speeds can be controlled, etc. Also was the fact that mechanical train stops were likely to function poorly in the Swedish climate with sometimes heavy snow falls and low temperatures. (Eighty per cent of the subway is on the surface.) To the surprise of several signal specialists, a comparative study showed that the first cost of a cab signal system, with continuous speed control, would be less than that of a system with wayside signals and intermittent train control. The fact that no mechanical train stops in the tracks were needed, with the cab signal system, made it justifiable to assume that the maintenance cost would also be smaller than for the intermittent system. It was, therefore, decided in 1947 that a cab signal system, with three aspects and two controlled speeds, should be installed in the Stockholm subway.

Centralized Control

The arguments for centralized trafffic control were: a smaller number of towermen required; and better facilities to check and control train movements. The arguments against it were higher first costs. However, the fairly short distances in the subway system made possible the use of direct-wire control and indication, and, with the use of telephone cables for the communication circuits, the first costs of a centralized system would be only slightly above those of a decentralized system. On the other hand, the annual savings in labor costs, due to the smaller number of tower operators required by the centralized system, were substantial. In all, it was found economically justifiable to centralize to the maximum. Thus, in 1949, it was decided that one signal tower should be installed for the southern subway section, and one tower for the western section. (The use of one tower for both sections was not considered, due to the fact that the connection between them could be built only several years after the two sections had been placed in service, and it would be impossible to install communication cables between the sections before the connection had been built.)

For the southern section of the

subway, which will not be described in detail in this article, a Union route-control machine, factory-wired relay racks, and complete cab signal and train control equipments were delivered by the Union Switch & Signal-Division of Westinghouse Air Brake Company which also designed the circuits. Wayside signals, which were used at the interlockings only, switch machines, impedance bonds, cables, etc., were delivered by the Swedish Ericsson Signal Company (L M Ericssons Signalaktiebolag) and other pieces of equipment by various Swedish manufacturing companies. The installation was made on the cars by the car manufacturing companies, and in the track and relay rooms and signal tower by Stockholm Tramways. The signal system was checked by two engineers from the Union Switch & Signal Division.

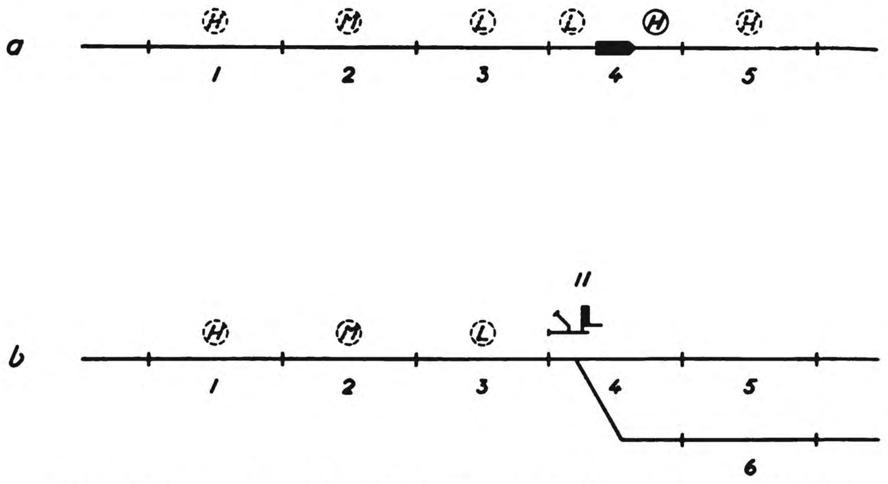


Fig. 1—Train receives cab signal aspects H, M or L in track circuits 1, 2 or 3, if preceding train is in 4 (a) or interlocked signal 11 is at stop (b).

Western Section

The present western section has 17 stations in 10 mi. of double track of which 3 mi. and 5 stations are in tunnel. The terminal station in the city is Kungsgatan, and in the western suburbs Vallingby. Alvik is a terminal station for a branch street car line. At Thorildsplan, two turnouts, which connect with the street car system, are used by work trains.

The signal system is of the continuous three-indication two-speed type without wayside signals, except at the interlockings. Switches and wayside signals are controlled from one signal tower. The cab signal, located to the left and front of the motorman, can display the following indications:

H (High) = 43 mph (70 kmph)
M (Medium) = 31 mph (50 kmph)
L (Low) = 9 mph (15 kmph)

A buzzer and a bell are located in the motorman's cab. The buzzer sounds when the train speed exceeds the speed allowed by the cab signal. This may occur when the motorman increases the train speed, and the cab signal is restricted to M or L. However, it happens normally when the train is running at maximum speed allowed, and the cab signal changes from H to M, or M to L. The bell sounds when the cab signal changes from M to L, and continues to sound until the motorman has acknowledged the change by operating an acknowledging switch.

Cab Signal Aspects

A train normally receives the H indication, and can thus travel at a maximum speed of approximately 43 m.p.h. The cab signal aspect changes from H to M and, later, from M to L when the train approaches a preceding train or an obstruction in the track, for instance a wayside interlocking signal at stop. Fig. 1 illustrates the cab signal change in a train approaching a preceding train or a wayside interlocking signal at stop. In 1-a, it is assumed that a train is traveling in track circuit 4. A second train receives the cab signal indications H, M, and L in the track circuits, 1, 2, and 3, respectively. It receives the L indication also in track circuit 4, where it may proceed to the rear end of the preceding train. In 1-b, it is assumed that wayside signal 11 displays a stop indication. An approaching train receives the cab signal indications H, M, and L in the track circuits 1, 2, and 3, respectively. In both cases, the block lengths are so long as to guarantee that the train will stop before reaching the preceding train or the wayside signal at stop.

When the buzzer sounds in the cab, the motorman is supposed to respond very quickly. In 1 to 1.5 sec. he should move the master controller to the off-position, and the brake handle to the full service brake position. If the motorman should fail to respond within the prescribed time limit, an emergency brake application will occur which brings the train to a full stop. The train may start, after approximately 20 sec., when the air pressure in the brake system has reached a prescribed limit, and proceed at the speed allowed by the cab signal. When the bell sounds, the motorman is supposed to acknowledge or there will be an emergency brake application. In track circuits where the speed must be restricted, due to steep down grades, short radius curves or other reasons, such track code which gives an H indication in the cab is eliminated, and cab signal aspects M and L only can be displayed.

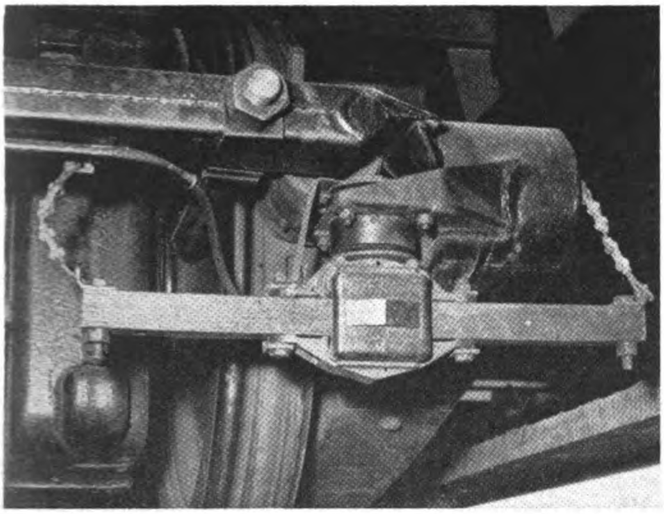
The aspects of the interlocking high signals which are used for the normal direction of traffic are as follows: (Note the left-hand traffic in Sweden!) Red—Stop and stay, Green—Proceed in accordance with cab signal indication. Two or three green lights indicate diverging routes. Red and yellow—Stop, then proceed prepared to stop short of train or obstruction (call on).

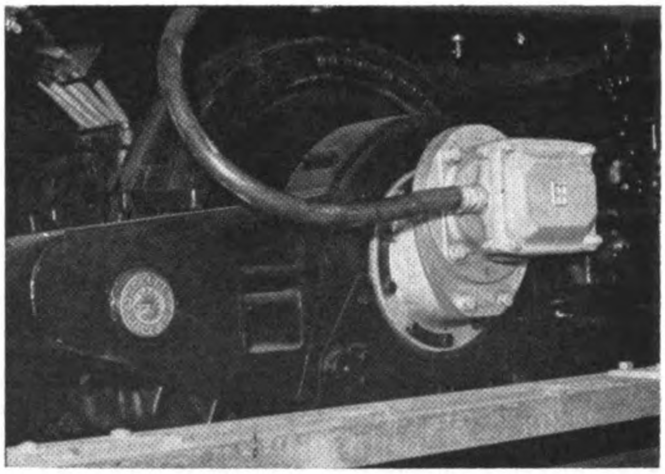
For train moves against normal direction of traffic, dwarf signals are used, whose aspects are as follows. Red—Stop and stay. Red and yellow—Stop, then proceed prepared to stop short of train or obstruction (call on). The cab signal enforces obedience with these wayside signal indications.

The track cricuits are normally fed from steady a. c. 75 cycle. When a train enters a track circuit, coded or steady energy is connected to the track, depending on the number of unoccupied blocks in front of the train. The 180-code displays an H, and 75-code an M indication in the cab, while no code or no current displays an L indication.

One Interlocking

When it had been decided that the control of all switches and wayside signals should be centralized to one signal tower, we found it necessary to choose a control system which was easy to manipulate. Such a system was available, the Union route control machine with line-of-light track indications. The control machine has provisions for the following indications: (a) Track occupancy as a red line-of-light; (b) Switch in transit as a red flashing light in the diagonal light unit of a switch or crossover; (c) Established route as a white line-





Above—Speed governor mounted on a journal box
Left—Receiver coils are mounted individually

of-light; (d) Wayside signal aspects as follows; Stop—Dark or red; Clear—Steady yellow; Call on—Flashing yellow.

(e) Exit and entrance lights as white track circuit lights at the exit and entrance of a route, respectively.

(f) Auxiliary switch control indication as a white light in the light unit or units representing the position of the switch.

(g) Third rail power-off indication as a flashing red line-of-light except where track occupancy is indicated as a steady red line-of-light.

All the indications mentioned above, except under paragraph g, are standard. However, the third rail power-off indication was designed for the Stockholm installation. The establishment of a route is carried out by the operation of entrance and exit buttons in the line-of-light, as is done as a standard in Union route control machines.

The signal tower is located at Alvik which is approximately in the middle of the western section. On the first floor there is a relay room, approximately 70 by 20 ft., a small room for storage batteries, and a repair room. On the second floor there is the control room, an automatic telephone exchange room, and various rooms for the signal maintainers. Other relay rooms are located at each end of each station. The average size of such relay rooms is 30 by 10 ft.

The cab signal and train control equipment box, housing filter, amplifier, decoding units, relays, and a test panel, is approximately 4 ft. by 20 in. Rearrangement of other pieces of equipment made it possible to install the cab signal box under the car body along one of the sides. The amplifier has one tube, and works on 35 volts d. c., which is the voltage of the car battery. It is adjusted to a nominal track current of 3.5 amp. The filter is a band pass filter for 75 plus or minus 4.5 cycles. This frequency was chosen to avoid disturbances from stray currents from the 50 cycles commercial source.

Although the use of a four-aspect cab signal system was at first considered, study showed that three aspects would be satisfactory. The top speed aspect was easy to decide, 43 mph (70 kmph), as this would be the top speed of the trains. The low speed aspect should be such as not only to prevent a severe shock if and when a train ran into an obstruction but also as to allow practicable operation of the trains. A speed of 9 (15 kmph) was considered to be satisfactory in these respects. The medium speed was chosen on the basis that the braking distance from medium speed would be half of the braking distance from the top speed. The buzzer and bell had to be such as to give distinctive audible indications. They were located in the ceiling in front of the motorman in his cab. The acknowledging switch, a pedal, was installed in the middle of the foot support.

A speed governor was needed to check that the speed allowed by the cab signal was not exceeded. We use the cab signal aspects H, M, and L which corresponded with the speeds 43, 31, and 9 m.p.h. respectively. Study of speed distance curves showed, however, that it would not be necessary to check the top speed, since only in very few station-to-station runs could a train exceed 43 m.p.h. and in those runs we were able to provide braking distance for the higher speeds. We could thus use a standard Union speed governor of the centrifugal type, having two sets of independent contacts. The governor was to be mounted on a journal box, and driven through a double pin connection directly from the end of a wheel axle. However, the standard governor was not made for the speed limits to be used on Stockholm subway, and it was therefore necessary to design a gear box. The governor was mounted on the gear box, and the whole unit was then installed on the journal box. The governor is so adjusted that the range between opening of the contacts, on acceleration and the closing of the contacts on deceleration, is not more than 5 per cent.

A pneumatic switch and two timing valve assemblies were needed, in addition to the above, for the train control. The pneumatic switch was to close its contacts, and thus prevent an emergency brake application, when the air pressure was sufficient in the air pipe controlling the service braking to cause a deceleration of 2.5 mphps. The timing valve assemblies were to delay the initiation of an emergency brake application a determined time interval, so as to give the motorman time to forestall the application. The equipment was installed underneath the car body, the pneumatic switch in the middle of the car, and one timing valve assembly in each end of the car.

The location of the receiver coils was decided from the electrical characteristics of the cab signal equipment. However, it proved to be difficult to find a satisfactory method of mounting the receivers on the trucks. In the beginning, the receiver coils were mounted on a horizontal crossbeam, but this method had to be discarded later, due to the very great accelerations (acceleration rates of more than 50 g were measured) that occurred in the mounting brackets. The beam was partly damaged in several cases. We have later changed to a method with the receiver coils supported individually.

As all elements in the equipment box—relays, decoding units, amplifier—were of the plug-in type, the relay rack in the box could be wired before the elements had been manufactured. This was of great advantage, as the amplifiers, and especially the relays could be delivered only a very short time before the completion of the western section. The wiring was made by the signal contractor, The Swedish AEG Company (Elektriska AB AEG).

The installation of the equipment box, cab signals, buzzers, bells, speed governor, receiver coils, and acknowledging switches, as well as the wiring between these pieces of equipment, was carried out by The Swedish Railroad Car Manufacturing Company (Aktiebolaget Svenska Järnvägsverkstadernä), and The General Swedish Electric Company (Allmänna Svenska Elektriska Aktiebolaget, ASEA), in the former corporation's workshops at Linköping, a city 94 mi. south of Stockholm. The plugging-in of relays, amplifier, and decoding units in the equipment box was made in Stockholm Tramways' workshop in Stockholm.

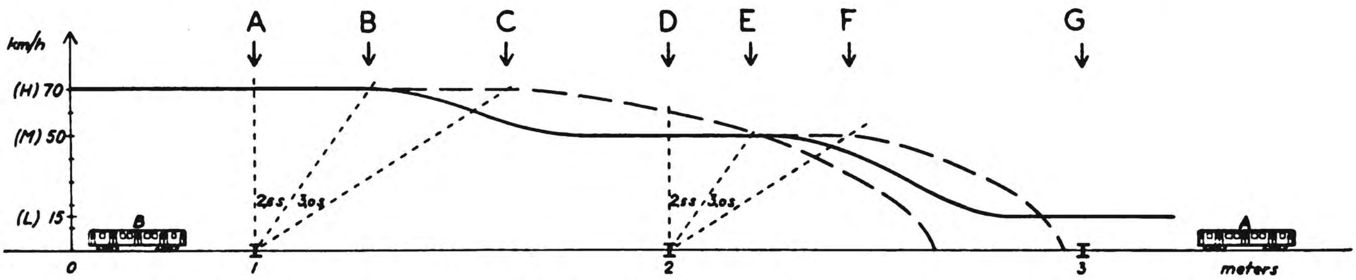


Fig. 2—Train B runs 43 m.p.h. When it approaches train A, motorman should decrease speed according to solid line. If he doesn't act on cab signal changes, emergency brake application occurs according to dash lines. A, D and G are insulated rail joints. B is cab signal change from H to M. Motorman moves master controller to off, and brake handle to full service braking. At C, if he hasn't acted emergency brake application occurs. At E, cab signal changes from M to L. Motorman moves master controller to Off, brake handle to full service braking. He acknowledges. At F, if he hasn't acted, emergency brake application occurs

Design of Wayside Equipment

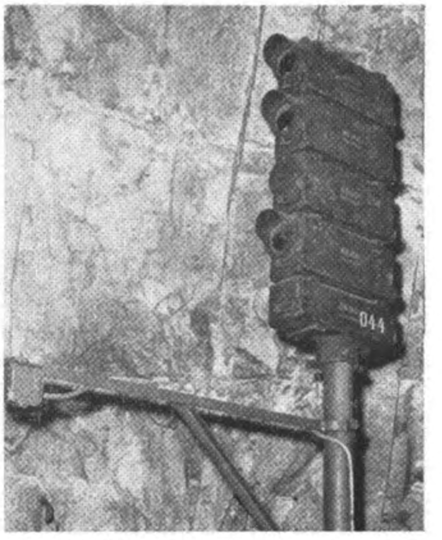
In the calculation of the block lengths we had to consider both that the braking distance should, at all times, be sufficient for the trains at maximum speed allowed by the cab signal, and that the headway should be 90 sec. The calculation was made in the following manner. When a track circuit transmits a code giving one cab signal aspect, and the next track circuit transmits a code giving another cab signal aspect, the signal change does not occur when the front end of the train passes the rail joint between the two track circuits, but only when the train has traveled for a certain time interval after having passed the joint. The time delay is maximum 2.5 sec., and is to prevent cab signal flashes when a train passes a joint at low speed. If the cab signal has changed to a more restricted speed aspect, and the train is traveling faster than allowed by the new cab signal aspect, the motorman is supposed to make a full service brake application, and to move the master controller to the off-position, as described in Fig. 2. If the motorman does not respond, an emergency brake application will occur after a delay period of 2.5 sec. plus or minus 0.5 sec. This time delay, minimum 2 sec., includes the time for the motorman's reaction and for his operation of the power and brake handles, but also the time needed for building up sufficient air pressure in the braking system. The maximum total time delay, after the train has passed the rail joint before an emergency brake application is thus 5.5 sec. The rate of emergency deceleration or the rate of service deceleration forestalling the emergency braking should be sufficient to stop the train before it has proceeded to the preceding train or the other obstruction in the track which has caused the restrictive cab signal. To the calculated braking distances, 20 per cent or more has been added as a margin of safety. On level track the track circuit length is approximately 600 ft. The influence of grades and curves on the braking distances has, of course, been taken in account when calculating the block lengths.

All circuits were designed by the Union Switch & Signal. A track circuit in approach of a wayside signal can receive coded energy if the wayside signal is at clear only. A track circuit in a route governed by a wayside signal cannot receive coded energy when occupied by a train, unless the train has passed the signal at clear. Interlocking high signals govern all routes, and in general the control limits extend only to the opposing signals. Thus, when a train has passed the control limits of a wayside signal, the signal can be cleared for a following train even if the cab signal of a train cannot be better than L, as the cab signal indication is controlled by full block lengths. Call-on signals have no track circuit control except that the track circuit in the approach to the signal must be occupied.

The switch operating motors are controlled by biased d.c. relays, one for operation to the normal position and one for operation to the reverse position. The last energized relay remains energized over a stick circuit until the other relay is operated. A circuit for manual release of a switch or crossover, in which the track circuit has failed, is arranged in such a way that, in order to operate a switch, the towerman has to move the auxiliary switch lever to the normal or reverse position and push an emergency release button a predetermined number of times, while an authorized person steadily depresses a button which is located in the vicinity of the switch in the field. The emergency push buttons on the control machine are normally sealed. The route selection circuits are the standard circuits used by the Union Switch & Signal for their route control machines.

Signals, switches, and track circuits have been numbered according to a system which is based upon the distance in dekameters (10 meters = 33 feet) from the center of the subway system. A signal which is located 12150 meters west of the reference point has thus been numbered 1215. Relays, transformers, resistors, and fuses, belonging to one signal, track circuit, or switch have been mounted in a group, and the elements within one group have always—where possible and practicable—the same position in an equipment row of a relay rack. The advantages of such an arrangement are several. It has enabled us to standardize the wiring diagram forms in which the majority of the wiring had been completed. On the forms we then only had to add numbers and special wiring. Another advantage is that it is easy for the maintenance crew to find a piece of apparatus when hunt-

Cab signal can display three aspects


Wayside signal in tunnel

ing a failure. A small disadvantage seems to be the fact that the system requires somewhat more relay rack space. All wiring diagrams have been designed for Stockholm Tramways.

The control machine has been designed by the Union Switch & Signal-Division and is of the route type. It is made in five sections, three of which have a length of 6.5 ft., and two of which are 5 ft. long. The total length is thus approximately 30 ft. The sections are in a U-shape.

All wayside signals have been designed (by the Ericsson Signal Company) so that the signal transformers, stepping down the voltage from 110 to 12 volts, can be housed in the signal heads. The high signals outside the tunnels have a special transformer unit, while all tunnel signals and all dwarf signals have one transformer in each light unit. The switch machines, which are manufactured by the Ericsson Signal Company, are equipped with two operating rods and two lock rods. When a switch is closed in the normal or reverse position it is mechanically locked.

As the track circuits were to be fed 75-cycle energy, impedance bonds for this frequency had to be designed. The design was made by the Ericsson Signal Company and the Swedish AEG Company. The bonds are of the resonated type and have an impedance of 4 ohms and a resistance of .0006 ohms.

In order to accomplish a uniform mounting of relays and other pieces of apparatus on the relay racks we wanted to have a transformer whose size was equivalent to that of a standard relay and plates for the mounting of resistors and fuses which were such as to fit on the rack. A new design of transformers of various types was made by the Swedish Gasaccumulator Company (Aktiebolaget Gasaccumulator, AGA) while a resistor and fuse mounting plate was designed by the Tramways.

Wayside Equipment

The signal tower and the 32 relay rooms at the various stations were built by various contractors, while all other installation work was made by the Tramways. The tower and the relay rooms were made of concrete. The height of each relay room is approximately 8 ft., and under the floor there is a 3-ft. high space for distribution of ground cables.

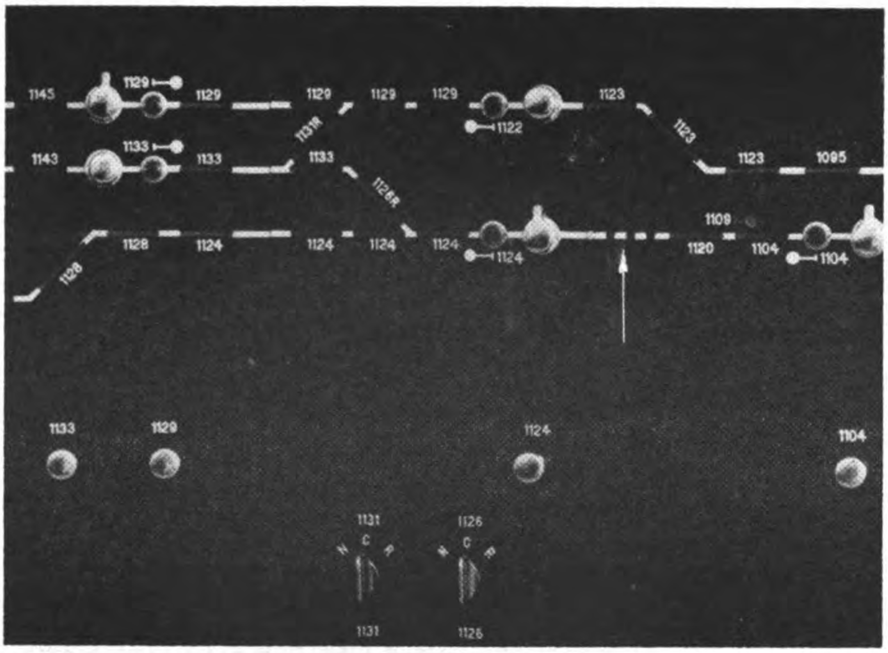
The power equipment in each relay room consists of one frequency motor-generator which converts 50 cycles into 75 cycles to be used for the track circuits, a.c. buses, fuses, voltmeters, and frequencymeters. All equipment, except the motor-generator, is mounted on two steel racks with a height of approximately 7 ft. and a width of approximately 3 ft. The equipment is the same in all relay rooms, and the mounting and wiring of the equipment on all racks was made in a workshop. On one of the power racks in each relay room there is equipment for automatic transfer from one source of energy to another, when the normal source fails.

In the permanent relay rack installation we wanted to have such wire markers and other tags which were easily readable, and of material which would remain permanent. These were deliverel by Actioncraft Products Company, New York, which furnished plastic sleeve type wire markers for wires terminating at relay bases and other pieces of equipment on the relay racks and plastic flat type markers for the terminal boards. We soon found that the wire markers could be used with great advantage also during the process of wiring. Thus, wire markers were ordered as soon as we had completed the wiring diagrams for a number of racks. When a quantity of wire markers was received, it was handed over to the wiring people who wired the racks from the information given on the wire markers only. This method of wiring proved to be successful. The wiring of all the racks to the whole installation was carried out in one place, and the work was divided into several steps. In the first step, terminals and tags were mounted on the terminal boards which were then installed on the top of each relay rack. In the second step, all pieces of apparatus, relay plug-boards, transformers, etc., were mounted on the rack. In the third step, all wiring was laid out in a wooden form whose size was equivalent to that of a relay rack and which, during the wiring process, was placed in a horizontal position and at a suitable height. In the fourth step, all cables were moved from the wooden form to the relay rack and all wire terminals soldered to the relay bases, and transformers.

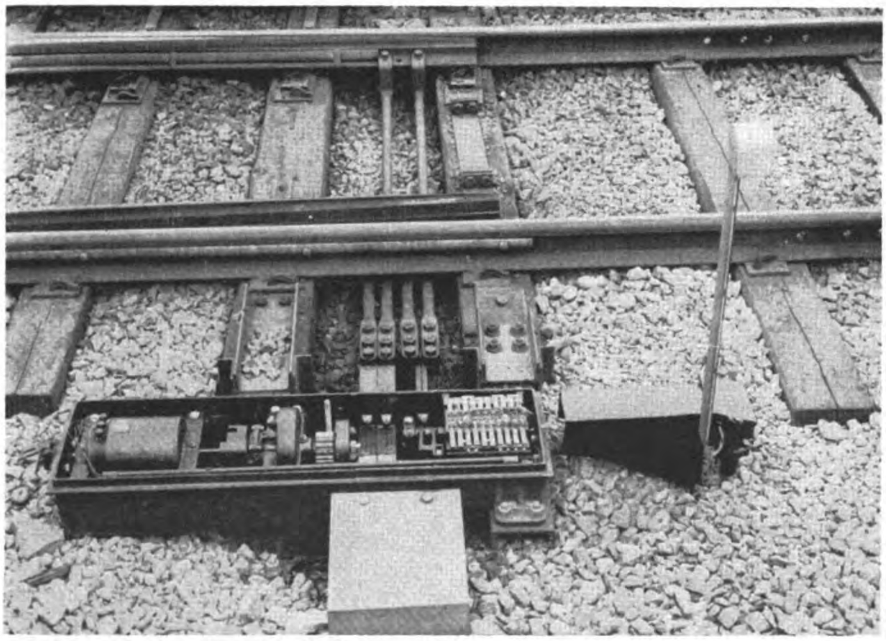
Wired racks were transported by trucks to the various relay rooms. When the racks had been installed, the wiring between racks and from racks to communication and signal cables was made. The ground cables were installed along the platform sides and the tunnel walls on brackets, but elsewhere along the line in concrete ducts. All cables were laid out from a cable car which was connected as a trailer to a locomotive. The speed of the cable train was up to 10 mph.

New Pin Brazing to Rail

A novel method used for connecting wires to the track might be of interest. The wires, provided at the ends with ligs, used to be fixed to the rails by welding. The Swedish Gasaccumulator Company invented, however, in 1951, a new method, called pin-brazing. A brazing gun is loaded with a brass pin, which has a two millimeter thick layer of brazing metal and flux at the end, and with a porcelain ferrule, which is to protect the arc melt from the air during the brazing process. The positive pole of a battery is connected with the brazing gun and the negative pole with the rail. When the part of the rail where the brazing is to take place has been cleaned by the use of a grinding wheel, the gun is placed into contact with the wire lug and the rail, whereupon the circuit is closed. The current passes through a magnet in the gun, and the magnet



Arrow points to four different colored lamps, used for identification of trains



Switch machine with cover open to show mechanism

lifts the chuck and brass pin a small distance. An arc is developed and brazes the lug to the rail. A time-control device in the gun interrupts the current after a predetermined time of approximately two seconds, and a spring pushes the metal pin down into the melted bath. A gasoline motor drives a generator which charges a 36-volt battery. The battery supplies 250-350 amp. during the very short brazing process. All equipment is mounted on a small truck. The quality of the pin brazed connection has proven to be good. Other advantages of the method are that it does not require manual skill, and that the work can be done fast.

Provisions have been made on the control machine front panel for a train identification system. The identification is to be indicated in the line-of-light at each station, and there are, in each track, four differently colored lights of the spotlight type. The identification is also to be made in the line-of-light in the approach of certain facing points on the line. We have planned to have a maximum of eight different indications which can be accomplished by the use of steady and flashing lights. The train identification in the tower is to be used in connection with illuminated train identification signs to be installed in the platforms. The identifications are also to be used for the automatic operation of certain facing points.

We have considered that a train identification system should have very little equipment on the cars, for two reasons. Equipment on the cars is exposed to violent vibration, and can therefore be assumed to require more maintenance than equipment on the wayside. Furthermore, all equipment on the cars has to be multiplied by the number of cars, and thus becomes expensive. The identification system must also be very flexible and reliable, and should function automatically.

The Union Switch & Signal-Division of Westinghouse Air Brake Co. proposed, in 1950, a system which fulfilled the requirements mentioned above. It was a system in which wayside apparatus along the track, a few hundred feet in the approach of a station, radiated carrier frequency form a wayside coil. When a train, having at its front end a coil resonant to the wayside carrier, passed by the wayside coil, the wayside equipment responded by picking up a relay. Similar cancellation equipment was to be installed at the exit of each station.

The Swedish AEG Company, in Stockholm, which was later licensed to manufacture the train identification system, developed the system further, and introduced the use of two horizontal wayside antennas at each detection point, and corresponding antennas on the train. In this system, the carrier frequency is not continuously transmitted.

The system works as an oscillator whose circuit is closed only when the two antennas of a train are parallel and adjacent the wayside antennas. Of course, no oscillation takes place if the car carried antennas are not connected via a coil and condensor. With this system, the resonant coil, on the car, can be made very small and light, weighing only a few ounces. One type of resonant coil is, of course, needed for each type of train identification. All cars and five stations on the western section should have the train identification system, including automatic operation of switches, in service at the end of 1953.

For the second subway system in Stockholm, which will be somewhat larger than the first system, we are planning to have only one tower for the whole system. This tower will control a territory of approximately 40 mi. of double track, with approximately 300 switches, 500 wayside signals, and well over 1,000 track circuits.