Automatic Block Installation in Copenhagen, Denmark

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The completion in the summer of 1934 of the electrification of the Copenhagen-Klampenborg line of the Danish State Railways involved, as was to be expected, considerable changes in the safety plant on this section. The number of block sections had to be increased, semaphore signals, owing to their visibility being impaired by the erection of the trolley suspension devices, required to be changed to daylight signals, and the point circuits must be made free from earthing and independent of the tensions in the rails and cable sheaths arising from the use of the track as return circuit for the 1 500 V DC traction current.

On electrification there had also to be considered an appreciable increase in the number of trains, making increased demands on rapid clearing of the block sections, and it was therefore decided to provide the line with automatic line-block, which at the same time would allow of a saving in wages for line-blocking staff, whereas extension of the existing manual line-block by increasing the number of block sections would have involved an appreciable increase of these expenses. After tenders had been considered L. M. Ericsson Signalaktiebolag were awarded the contract for the delivery of the projected automatic block installation.

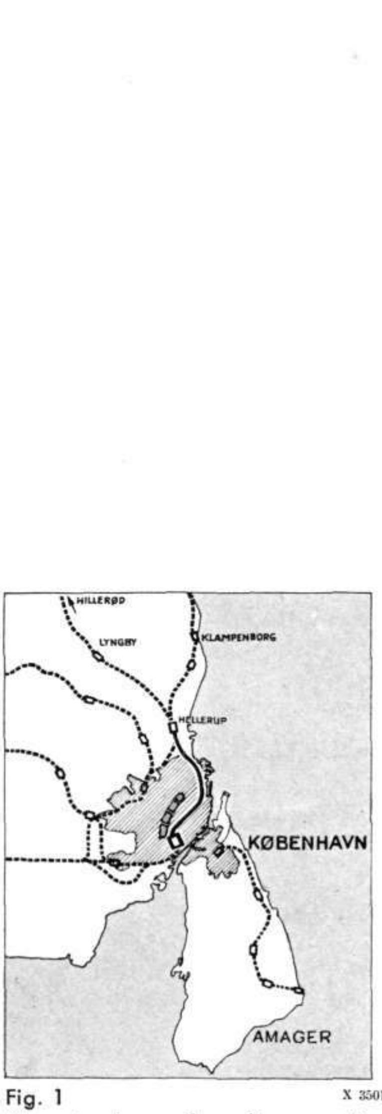


Fig. 1 X 3501
Map showing railway lines meeting at Copenhagen

As may be seen from Fig. 1, the Copenhagen—Hellerup line consists of two double tracks, the eastern of which carries traffic to Klampenborg and stations north of Klampenborg, while the western takes traffic to stations between Copenhagen and Klampenborg as well as to the northern line (Hellerup—Hillerød—Helsingør). On the western electrified double track some 120 trains run daily in each direction and on Sundays and holidays the number rises to about 150, at certain periods amounting to 11 trains per hour, so that perfect functioning of the block system is very necessary.

Signals

Between Copenhagen and Hellerup there are the following stations: Vesterport, Nørreport, Østerport, Nordhavn and Svanemøllen, all of which are provided whith central platforms, see Fig. 2. At these stations, block signals are located at the ends of the platforms and likewise the entrance signals for the stretch are provided with distant signals at 400 m distance. The greater part of the stretch between Vesterport and Østerport lies in a tunnel, Fig. 3. Further, it may be seen from Fig. 4 what signals are comprised in the plant.

At Østerport both entrance and departure signals for the western double track may be operated either manually or automatically, according to the position of the switching lever concerned at Østerport station. This is done to allow of shifting of the points at the station when the signals are set at »stop».

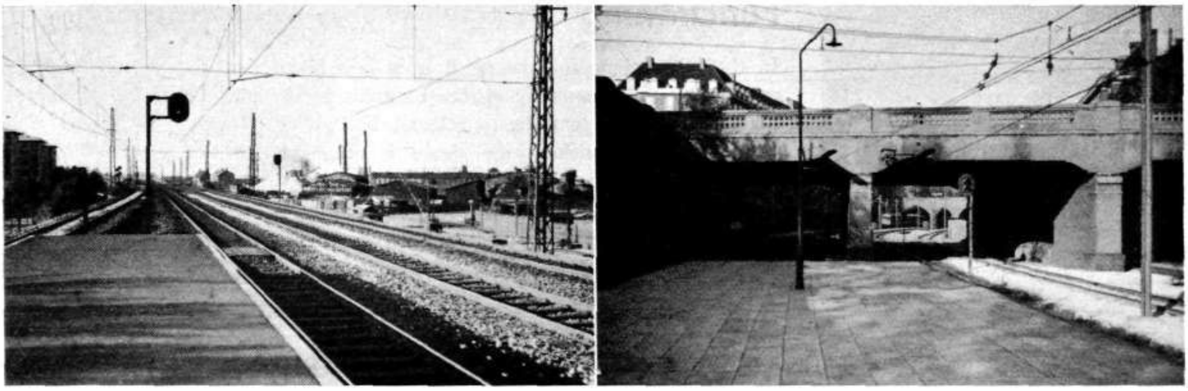


Fig. 2 and 3 X 7085
Copenhagen—Hellerup line
seen left, from north at Nordhavn Station
right, from east at Vesterport Station

All the signals are made as daylight signals with red and green lights for the main signals and yellow and green flashing lights at the distant signals. The lamps on the signals are provided with two filaments and in the lamp circuits there are inserted supervisory relays with built-in rectifier valve which connect up the spare filament if the main filament burns out. The connection of a spare filament is indicated by a control lamp lighting up in the relay cubicle concerned. When the main filament of a lamp burns out the lamp must be replaced as soon as possible, as the spare filament is only reckoned to burn for 300 h, while the main filaments are estimated to last for about 3 000 h with the tension used.

Track Relays

To supervise the track clearance of the block sections and for the control of the signals there is fitted at one end of the block section a two-phase vane relay, one coil of which, the track phase, is connected direct to the two rails, while the other coil, the auxiliary phase, is connected to 220 V AC. The track-relay armature can take up three positions: plus position, zero position and minus position. On inversion of the track phase the armature moves from plus position to zero position and on short-circuit of the track phase it goes to minor position. At the other end of the block section a track transformer is connected which puts the rails under suitable tension, about 1.5 V. The relays and track transformers are generally fitted in relay boxes, see Fig. 5, which, in addition, house cable terminal boxes, fuses, resistances, etc.

Impedance Connections

To allow of the return of the traction current through the rails in spite of the rail insulation, at each end of the block sections there are inserted impedance connections, Fig. 6, *i. e.*, inductive resistance coils with very low DC resistance, 0.0007 ohm, and high AC resistance, about 3 ohm. The impedance connections consist of an iron core on which are placed two coils: a heavy wire copper coil the ends of which are connected to the two rails and the middle of which is joined to the middle of the adjoining impedance coil and to earth, for which last the parallel running double track is used, and a thin-wire coil the ends of which are connected to a condenser which is so arranged that the AC resistance in the heavy coils is the greatest possible, *i. e.*, that there is resonance between the two coils.

Fig. 4 X 7086
Signalling plan of Copenhagen—Hellerup block installation

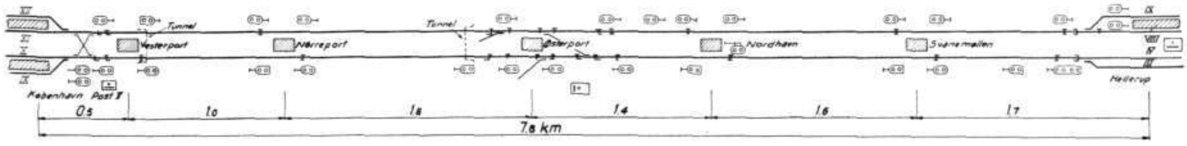


Fig. 5 X 3502
Relay cubicle

Fig. 6 X 3503
Impedance connections

Functioning

In the stipulations for the plant it is laid down that the signals, with the exception of the manually operated signals at Copenhagen and Hellerup stations, shall normally indicate »clear», but go automatically to »stop» when the block section behind the signal is occupied. Further the condition for return to »clear» is that the block section after the signal is free, and that the signal immediately following shows »stop» and that the relays of the latter block section have functioned properly during the passage of the last train.

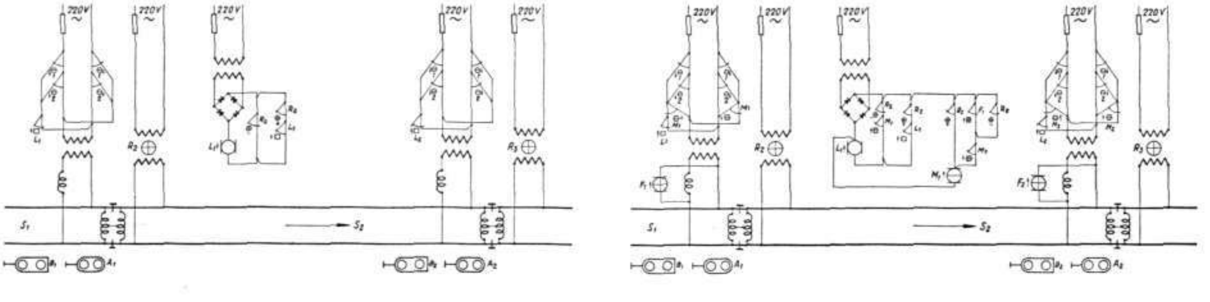
Fig. 7 shows the diagram according to which the block system was originally installed. The passage of a train has the following effect: before the train enters block section S_2, track relay R_2 is in plus position, control relay L_1 is attracted, and signal A_1 indicates »clear». When the train enters section S_2, relay R_2 is short-circuited and its armature goes into zero position, whereupon both positive and negative contacts on the relay are broken. The control relay L_1 is without current and the signal A_1 changes to »stop». When the first pair of wheels of the train enters section S_3, track relay R_3 is short-circuited, whereupon control relay L_2 is without current and signal A_2 is set to »stop». On this the track current to section S_2 is reversed which has the effect of making the armature of relay R_2 go to minus position when the last pair of wheels of the train have left section S_2, and relay L_1 receives current again and sets signal A_1 at »clear». When the section is again free and the signal A_2 has gone to »clear», the current to section S_2 is again reversed, whereupon track relay R_2 changes from minus to plus position. As relay L_1 is provided with delayed action its armature remains attracted while relay R_2 changes from minus to plus and the signals and relays of block section S_1 are restored to normal position.

As stated, the mid point of the impedance is connected to the mid point of the adjoining impedance and to the parallel running eastern double track to ensure the largest possible cross section for the return circuit of the traction current. This circumstance, however, provides the possibility that in certain conditions a »clear» may arise in an occupied block section, *viz.*, when two rail joints are defective at one time and a train happens to be between these defective joints at the same time as there is a train in the section immediately following. A train between such joints will, on account of the connection of the double-track to the mid point of the impedances, not short-circuit the track relay, and when a train in the following block section causes an inversion of the current the track relay will go into minus position and the signal will indicate »clear».

As a defective rail joint, in view of the above-mentioned connection with the parallel running double track, does not show itself by setting the track relay at zero position and the signal at »stop», the occurence of two defective rail joints at the same time may very well happen. This situation, moreover, arose during testing of the plant when it was to be taken into service. To eliminate the risk there was inserted at the feeding side of every block section an extra track relay F and, parallel with each control relay, an auxiliary

Fig. 7 and 8 X 1491 X 1492
Diagram of block installation
left, original diagram, right, final diagram

a	distant signal		
A	main signal	M	auxiliary relay
F	extra track relay	R	track relay
L	control relay	S	block section



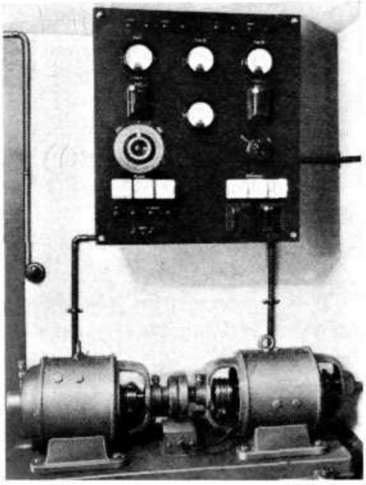


Fig. 9 X 3504
Rotary converter
for reserve current supply

relay *M*. The function of the track relay was to hold the auxiliary relay attracted during the whole time the train was passing the signal. The relays thus added are moreover connected to the necessary contacts, as may be seen on the current diagram in Fig. 8, which is that now applying to the plant. As may be seen, the auxiliary relay normally receives current, but is cut off when the last wheels of the train quit the following block section. As the relay has delayed action it causes a delay in the inversion of the current which the red-light supervisory relay establishes during the passage of a train, so that the track relay for the preceding block section goes into plus position for an instant, about 1.5 s, before it goes to minus position. When the last-named track relay thus goes into plus position, it connects the corresponding auxiliary relay and when the track relay, on account of reversal of current immediately afterwards, goes into minus position, the control relay belonging to it receives current again and the signal returns to »clear».

As a study of the diagram will indicate, the armature of the track relay changes position during the passage of a train in a clearly defined order, *viz.*, plus, zero, plus, minus, plus; for any other order the signal will remain at »stop» and thus also if the order is that occuring when a train is between two defective rail joints at the same time as the next block section is occupied. With the diagram employed a defective insulation will have the effect of showing »stop» to a train in the nearest block section.

As may be seen, in the plant here described there has been taken into account to a great extent the possibility of false »clear» signal on weakness in various parts of the plant and safety provisions have been made for supervision of the proper functioning of the relays and signals in all circumstances. This has naturally caused the installation to be somewhat more complicated than the system most often employed in America, where it is considered that the risk of faults in the track relays may be ignored. Still no inconvenience has arisen with the method selected here, which provides safeguards which it was desired not to dispense with.

Current Supply

The installation uses AC 3×380 V, 50 c/s throughout. The section between Copenhagen and Østerport is fed from Copenhagen and the section Østerport—Hellerup from the last-named station. For this purpose a special supply cable has been laid along the whole stretch. The cable comprises 7 conductors, *viz:* 3 of 4 mm^2 area and 4 of 1.5 mm^2. The three 4 mm^2 and one 1.5 mm^2 conductor are employed for the track apparatus, operating circuits and the like, while the remaining three 1.5 mm^2 conductors are used for lighting circuits. In order to avoid the quite strong reactive current in the track circuits, transformers have been inserted at some points of the network.

As a reserve there has been installed at Copenhagen (Signal Cabin V) a converter, Fig. 9, for converting the town mains 220 V DC current to 3×380 V AC, 50 c/s, but normally current is delivered from AC mains. At Østerport the two feed cables, normally separated, can be connected together, so that the whole current supply can be furnished either from Copenhagen or from Hellerup. In addition there is a reserve petrol generator at Hellerup station for the block installation, which is automatically connected in when drop in tension occurs.

At Hellerup and Østerport there are converters, by which the lamp tension for the block signals can be changed from day to night tension. This is done by connecting the signal transformers during the day to 380 V between two phases, while at night they are connected to 220 V between phase and neutral.