Technical Meeting of the Institution

held at

The Institution of Electrical Engineers

Thursday, October 18th, 1956

The President (Mr. J. C. KUBALE) in the chair

The **President** announced that it had been the custom to read the Minutes of the Annual General Meeting at the next meeting in London to follow it. The Council now proposed that such minutes should be read at the next Annual General Meeting, which seemed to be more appropriate.

Since the last meeting, the Institution had suffered a sad loss by the death of Mr. J. E. Mott, and all members knew what a great help he had been to them. A member of Council for several years, he did a great deal of work both at home and abroad, and for many years had served as Master of Ceremonies at the Annual Dinner and Dance. The Council had recorded a minute expressing their deep regret and a brief appreciation of his work.

The **President** then introduced Mr. I. Boberg and Mr. James Steffenson, who were present for the first time since their election to membership. He also welcomed Mr. J. S. Fides, an overseas member from India.

He then said that the Institution was privileged that evening to have a paper read by two distinguished signal engineers from Denmark, Mr. James Steffensen and Mr. Wessel Hansen. The paper was in two parts, the first written by Mr. Steffensen and the second by Mr. Wessel Hansen, and each part would be read by its author.

Signalling Practice on the Danish State Railways

By JAMES STEFFENSEN (Associate Member)
and W. WESSEL HANSEN

Diagrams—Inset Sheet No. 8

PART A
SIGNALLING AND OPERATING METHODS
(JAMES STEFFENSEN)

Extent of System and Traffic Density

The Danish State Railway system is shown by heavy lines on the map (fig. 1). It comprises a total of 2574 km. of standard-gauge lines besides 8 ferry routes. Of the railway total, 712 km. of line are double track and 1862 km. are single track, while 49 km. of double track and 11 km. of single track in the Copenhagen suburban area are electrified on the 1500 v. d.c. overhead system.

The busiest stretch of main line in the country is the Copenhagen-Roskilde section (31 km. of double track), which in the summer of 1956 was scheduled to carry a maximum of 214

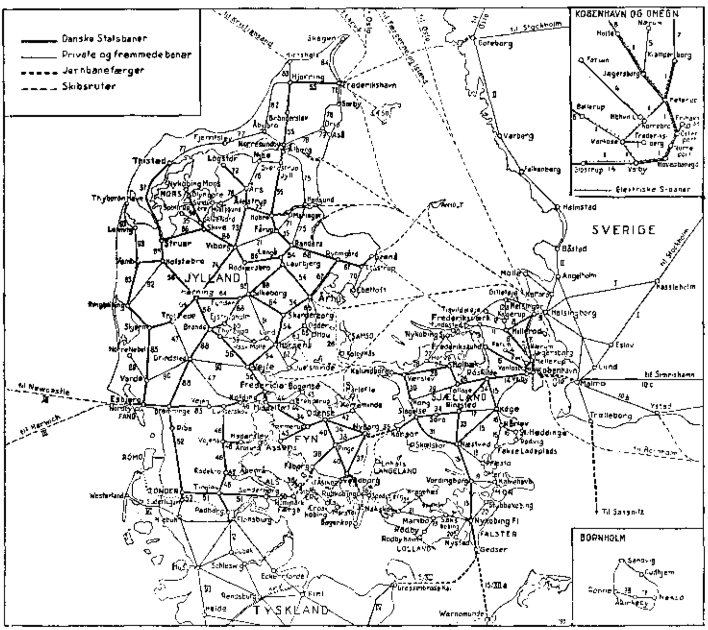


Fig. 1 Railway Map of Denmark.

ordinary trains (both directions included) on Saturdays. The equivalent figures for the remaining double-track main lines are from about 125 down to about 40 trains per day. The two busiest single-track main lines are Vordingborg-Gedser and Vamdrup-Padborg with maxima of about 50 trains per day on certain sections.

On the electrified suburban lines around Copenhagen, which are worked to regular-interval schedules, the maximum train density is, of course, much higher, reaching 435 trains per day on the double track between Copenhagen Central Station and Hellerup and 120 trains per day on two short single-line extensions.

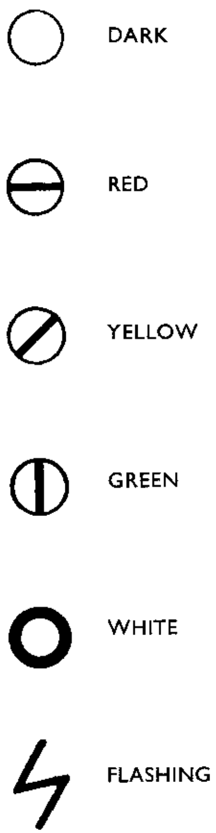


Fig. 2 Colour Symbols used on Signal Diagrams.

The average number of trains on branches is as a rule around 20 per day, although one Copenhagen suburban line with regular interval services reaches 60 trains a day on the innermost section.

The speed limit is 120 km.p.h. on first class main lines, 100 km.p.h. on secondary main lines, and 75 km.p.h. on branch lines.

General Remarks on Signalling and Signal Aspects

As per September 1st, 1956, out of a total of 418 stations equipped with interlockings, 310 with 371 signal boxes have mechanical frames, while 56 with 92 boxes have electric frames with mechanical interlocking, and 52 with one box each have all-relay interlockings.

As will be seen from the figures quoted, the majority of station interlockings have only one signal box. This is possible because the Danish tail signal is also visible along the train, one lamp being attached to each side of the last vehicle. All new interlockings, even the largest, will be controlled from one signal box.

Besides the station interlockings, there are 54 automatic signals, chiefly in the Copenhagen area.

Lock-and-block is only employed on 331 km. of line, of which 302 km. are double track and 29 km. single track. The number of block sections comprises 217, of which 93 are automatic and 124 manually operated. On the remaining 2243 km. of line, train working between stations is regulated by "telephone block." Trains are offered and accepted by telephone, the messages exchanged being entered in the train registers at both stations. There is no other form of visual reminder such as that provided by British block instruments. Although in Denmark there have fortunately only been very few train collisions between stations, telephone block is definitely not satisfactory on main lines under present-day conditions, and efforts are being made to extend the use of lock-and-block considerably and to replace the obsolescent manual block apparatus by automatic equipment as quickly as funds and other modernisation work permit.

On double-track lines, right-hand running is in force. Signals are, where possible, placed immediately to the right of (or over) the track to which they apply. Semaphore signals are displayed to the right of the post and are always of the upper-quadrant type. In colour-light signals, individual lamp units are employed throughout. The geometrical form of the background shade depends on the type of signal; for instance, stop signal shades

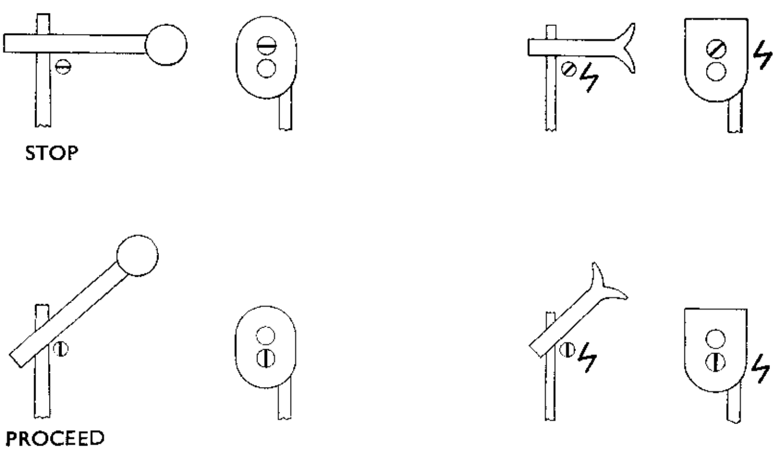
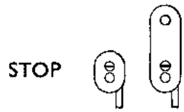


Fig. 3 Two-Aspect Stop Signals (left) and corresponding positions of Two-Aspect Distant Signals (right). All types of signals are drawn to the same scale.

have rounded top and bottom, while distant signals have rounded bottom only.

On the majority of the lines of the Danish State Railways, signalling equipment is of a much less elaborate nature than in Great



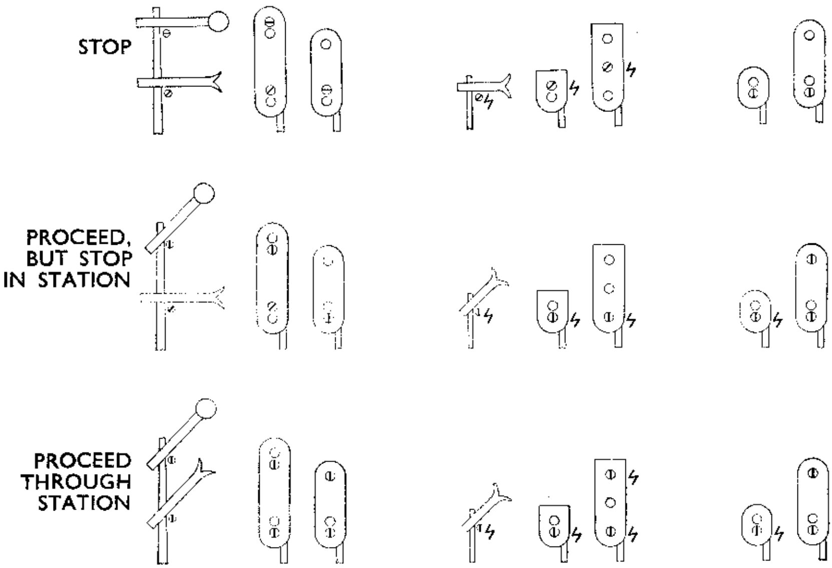
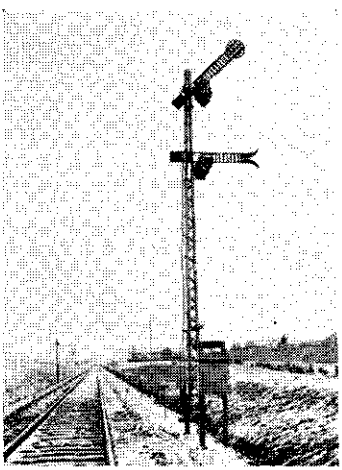


Fig. 4 Three-Aspect Home Signals (left) and corresponding positions of Distant Signals (centre) or equivalent Multi-Aspect Stop Signals (right). Home Signals without Yellow Light are only employed on Branch Lines. Multi-Aspect Stop Signals with Flashing Green Light are only employed on Electrified Suburban Lines.

Britain. Generally speaking, starting and shunting signals are only provided at junctions ; these principles are still followed in new work on branch lines, while more complete equipment is of course already today provided on busy main or suburban lines.

Speaking of present-day conditions, at a wayside station on a single-track line the only signals provided are, as a rule, a home and a distant signal for each direction of running. The home signal is generally placed 150-250 metres from the loop points, and shunting within station limits is permitted as far as a shunt limit board 50 m. inside the home signal, even when a train has been accepted from the neighbouring station. The distant signal, where provided, is placed at a fixed distance in rear of the home signal (800 m. on high-speed main lines and 400 m. on other lines). To assist the drivers of approaching trains, " distance boards " are provided at fixed distances of 400, 800 and 1,200 m. in rear of the home signal. The distant signal will thus always be next to a distance board. At stations which are regularly passed by non-stopping trains, a starting distant is fitted under the arm (or light) of the home signal, even if there is no starting signal; it is thus not necessary to show a hand signal to non-stopping trains. The distant signal proper normally only indicates whether the home signal is " on " or " off," but on high-speed lines three-aspect colour-light distant signals are provided, so that the aspect shown by the starting distant can also be indicated. The current aspects of the most common stop and distant signals, and the symbols used, are shown on figs. 2 to 4, while some typical signals are shown on figs. 5 to 7. It will be noticed that distant signals always show flashing light.



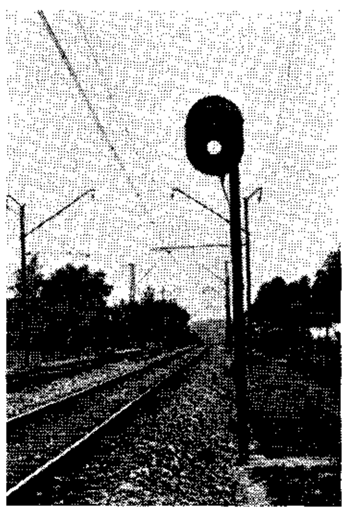


Fig. 5 Three-Aspect Semaphore Home Signal.

Fig. 6 Automatic Multi-Aspect Colour-Light Intermediate Block Signal on Electrified Line.

Until 1953, a number of home signals were fitted with auxiliary route indicators showing a vertical or slanting illuminated white line, but all route indicators have now been rebuilt as speed indicators, in agreement with the general trend on Continental railways.

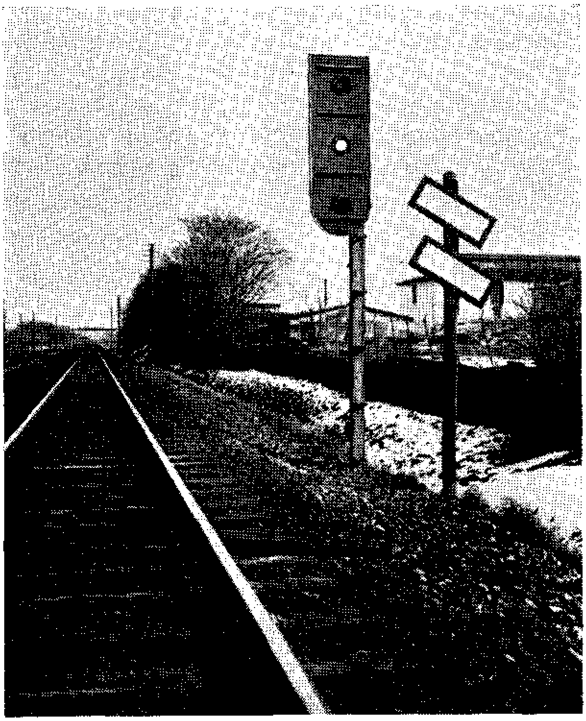


Fig. 7 Three-Aspect Colour-Light Distant Signal.
The adjacent twin Distance Board indicates that the Home Signal is 800 m. ahead.

The speed aspects now in force are shown on the photographs figs. 8a to 8d. A more flexible system would certainly have been obtained by displaying a figure, for instance " 8 " to denote 80 km.p.h., but this would have meant reduced sighting distance because the figures 3, 6, 8 and 9 are of the same general shape. The speed indication is at present only given at the home signal, and the sighting distance therefore becomes of primary importance. The " high speed " aspect does not authorise a definite speed which is the same at all stations, but where the permitted speed is lower than the ruling speed on the line in question, permanent speed-restriction boards are erected as a reminder to drivers. While temporary speed restrictions are in force, the aspects shown by the speed indicator are altered accordingly.

The " short route " aspect informs the driver that the route is considerably shorter than other arrival routes from the line in question, and that the driver must be prepared to stop short of a buffer stop (e.g. in a short bay track) or a fixed signal at danger (e.g. where part of the arrival track is occupied).

It will be noticed that the " short route " aspect is built up of the medium and low speed aspects. As failure of one half of the " short route " aspect must under no circumstances leave the other half illuminated, thus producing a less restrictive aspect, a

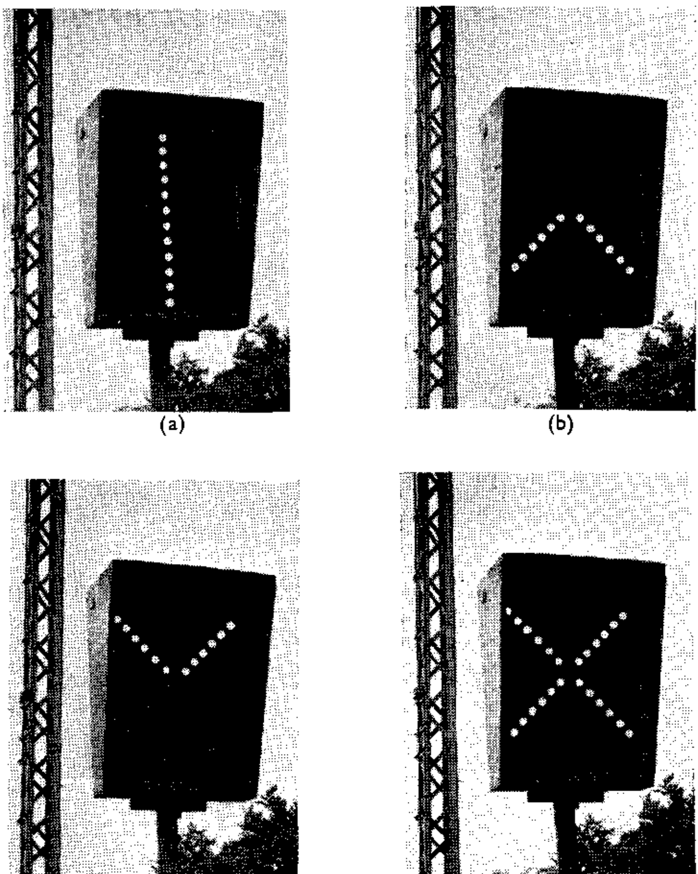


Fig. 8 Speed Indicator Aspects.
(a) " High Speed " (see text).
(b) " Medium Speed " (50 km.p.h.)
(c) " Low Speed " (30 km.p.h.)
(d) If Home Signal is Clear : " Short Route " (see text).
If Home Signal is at Danger : " Stop and Proceed " (see text).

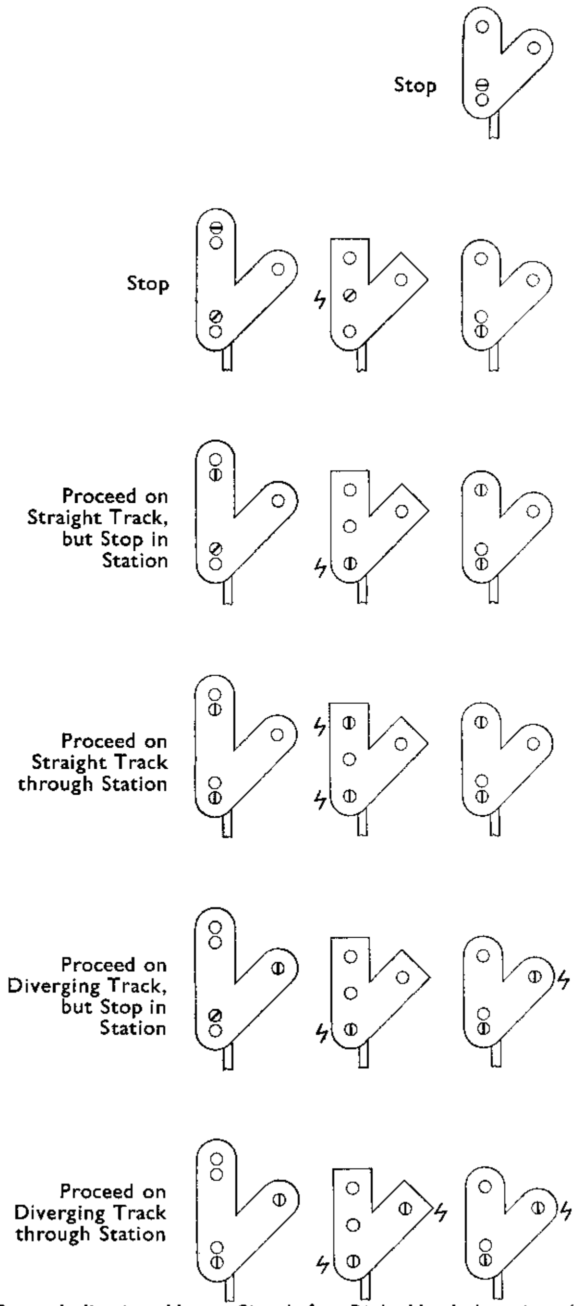


Fig. 9 Route-Indicating Home Signal for Right-Hand Junction (left) and corresponding positions of Distant Signal (centre) or equivalent Multi-Aspect Stop Signal (right).

special circuit had to be designed which ensures that "short route" will be shown either complete or not at all.

With the home signal at danger, the "short route" aspect of the speed indicator is also used as a calling-on signal signifying "stop and proceed, prepared to stop clear of possible obstruction."

At the entrance to a station, route indications are, in principle, only provided at facing junctions where through running occurs regularly over both routes. The route indication is given by position-light colour-light signals. The various possible aspects for a right-hand turnout are reproduced on fig. 9, while fig. 10 shows an actual route-indicating home signal. If through running only takes place over one route, no route indication is given except in special cases, for instance where an electric train taking the wrong route would tear down the catenary.

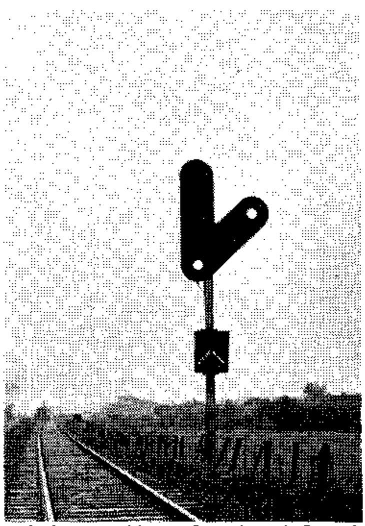


Fig. 10 Route Indicating Home Signal with Speed Indicator.

Starting signals were formerly only provided to a very limited extent, apart from stations on lines equipped with lock-and-block. An extensive programme is, however, in preparation to provide starting signals throughout on all except branch lines. Starting signals are now always fitted with signal replacers.

The signalling equipment at the exit from a station consists (where provided) either of an independent starting signal for each station track or of an advanced starting signal in connection with either a "route signal" for each station track or a combined starting and shunting signal (rather unfortunately named " platform starting signal ") for each track. The latter signal in principle shows a single coloured light for running movements and twin white position-light aspects for shunting movements. The various aspects are shown on fig. 11 and an actual signal on fig. 12. The subsidiary aspects are also used in position-light ground signals.

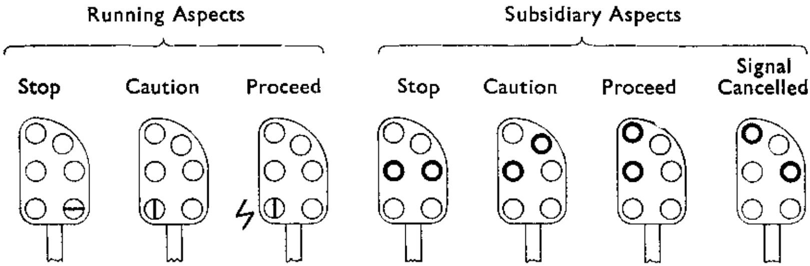


Fig. 11 Platform Starting Signal. The " Signal Cancelled " Aspect orders the Driver to act as though the signal did not exist ; this aspect is used when control of electrically worked points is transferred from Signal Box to site. The signals are drawn twice as large as the signals shown on other diagrams.

It will be noticed that the subsidiary " stop " and " caution " aspects correspond to the British ones, with " caution " modified to correspond to right-hand running. Platform starting signals can also be used to divide a station track, the red aspect being used to denote the point short of which the entering train must stop.

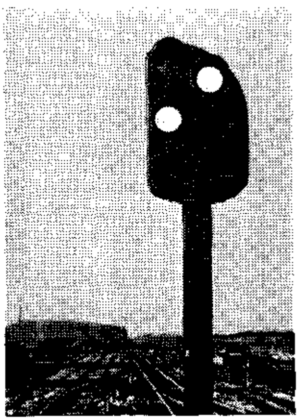


Fig. 12 Platform Starting Signal.

Where there is a diverging junction at the exit from a station, all types of starting signals can, if required, be fitted with route indicators which show an illuminated letter built up from individual pin-point white lights.

When " stop and proceed " is shown from signals other than home and inner home signals, it takes the form of flashing red light.

The system of aspects described has been built up in such a manner that all main running signals show coloured light and all auxiliary signals white light. This distinction is considered to be advantageous in assisting easy and certain identification of signals.

General Remarks on Interlocking

As a rule, points or crossovers connecting the loop with the main running line or lines are worked from the signal box, while siding connections are hand operated by ground levers. Siding connections are always provided with catch-points or scotch-blocks, but protection of running tracks against shunting movements on other running tracks has hitherto not been considered necessary, as shunting may only take place when permitted by the station master. In future, however, the through track or tracks at stations on main lines will be completely protected either by trap-points or scotch-blocks or by shunting signals.

In electric interlockings, control of electrically operated points can often be transferred from the signal box to special control switches on site which can be operated by the shunter. All points in running lines are fitted with point indicators of the German type to assist shunting operations, and points worked from the signal-box are track-circuited to prevent inadvertent movement under a vehicle. In older installations, such track circuits are, however, not in action when the points are controlled by the local switches. Mechanical depression bars are not used.

Points which are worked from a distance are always fitted with trailable facing-point locks, but mechanically worked facing points in running lines have also an extra locking mechanism, controlled from the signal box, which proves and bolts both detector rods before the appropriate signal can be cleared. As bolting evidently makes the points untrailable, points must normally be unbolted while no route is set up. The trailable facing-point lock, which only locks the closed switch blade, is found in several types, all of German origin, which act either directly on the stock rail or indirectly through the point mechanism. Points which have been trailed may not be traversed in the facing direction until inspected, found in order, and clipped, but usually no damage is done if the points were not bolted. Trailing of remote-controlled points is indicated visibly and audibly in the signal box.

Siding crossovers are generally worked by ground levers on site, and ground frames in the British sense are not employed, although in some old mechanical installations a " detached signal box" is found which is only attended when the loop is in use or during shunting operations. Siding connections are bolted either by an independent mechanism worked from a separate lever in the signal box, as described above, or by means of key-locks which act on the ground levers and prove the facing-point locks in the correct end position.

In mechanical interlockings, double-wire operation with equipment of German type is universal for both points and signals.

Simplified Operating Methods

During periods where trains cross or pass, or follow each other in close succession, a station must be in charge of a fully-trained " train dispatcher," who is authorised to offer and accept trains and to make responsible decisions involving, for instance, changes in the order of running on any particular section of track adjacent to the station. Such " train order stations " form the base on which traffic operation in Denmark is built up.

In intervals of light traffic it is, however, often possible to reduce working expenses by dispensing with the train dispatcher at wayside stations, enabling these to be worked by a less-qualified " station operator " or even to be unattended at train-time. Stations which are sometimes train order stations and sometimes halts are designated with a special sign (an open triangle) against the station name in the working time-table. Far the greater part of these "△-stations " are not yet equipped with starting signals, and special measures must therefore evidently be taken to prevent stopping trains from leaving unless it is safe for them to do so.

The following procedure is employed when a train is due to start :—

At stations which are always train order stations and at △-stations which are in charge of a train dispatcher or a station operator, the person in charge gives the right-away to the guard, who then gives the driver the signal to start. At stations which are always halts and at △-stations which are unattended, no right-away is shown from the station, and the guard on his own responsibility gives the driver the signal to start.

As it is thus essential for the guard of a train standing at a △-station to know when to depend on the right-away from the station and when not, a special supplement to the working time-table is published which contains these data. As there have been several cases where a train has left without authority from the person in charge, the guard believing the station to be unattended, a special signal is now being introduced at △-stations which are sometimes unattended at train-time. This signal shows three white lights in a triangle when the station is unattended. At △-stations, the guard must therefore in future always receive either the ordinary right-away from the person in charge or the " station unattended " signal.

At △-stations on single lines where trains run in either direction while the station is unattended, the two home signals are normally conflicting but must of course show a clear aspect for their respective trains. A good but expensive method which has been employed on a certain number of small all-relay interlockings is to let each train clear its own home signal by actuating a treadle 600-800 m. in rear of the signal in question. A much cheaper method, which can also be used on mechanical interlockings, and which has now been standardised for future work, consists in altering the locking so that both home signals can be cleared at the same time when certain conditions have been complied with. These include switching out the telephone instrument used for offering and accepting trains, illuminating the " station unattended " signal, and switching in an emergency telephone on the platform for the use of the guard. The king-lever which controls these functions may only be worked by the train-dispatcher going off or on duty ; it is locked reverse while the station is unattended.

At the present time (September, 1956), 51 out of a total of 76 △-stations which are sometimes unattended at train-time have been equipped for simplified working in one of the manners described. The cost of the technical alterations involved is, on the average, covered by one year's savings, so that this form of simplified working is a good investment.

PART B
RECENT TRENDS IN SIGNALLING TECHNIQUE
(W. WESSEL HANSEN)

Until about 1935, the Danish State Railways in principle applied the signalling technique developed by the signalling industry. Frequently the technique varied with each installation, naturally resulting in many drawbacks ; for instance, the staff was not always fully conversant with the installation they were to handle and maintain.

The application of several systems here had the advantage, however, of enabling one to follow, pretty thoroughly, the development of signalling technique abroad. Much experience was gained, thus creating a sound basis for the introduction of a new standard system after the cessation of the last world war.

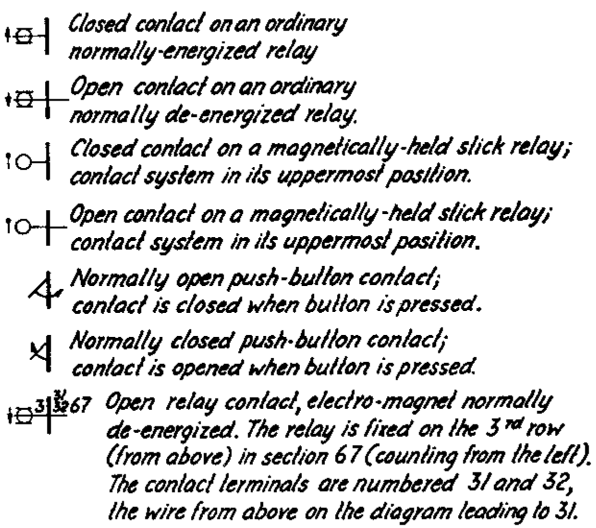


Fig. 13 Contact Symbols and Terminal Numbering.

Circuit Technique

As is known, the circuit technique for signalling installations is based on a number of details, the explanation of which is difficult to set up systematically. The object here is to give some information on a few of the points which must be taken into account in relation to safety circuits.

In all-relay interlockings, far more relay contacts are employed than in the mechanical-electric systems previously used. Much importance is attached to the execution of the circuit diagrams in order to ensure that the individual (but numerous) contact and coil symbols are clearly distinguishable. Moreover, emphasis is laid on an unambiguous and simple characterization of the placing of each contact on every relay.

Fig. 13 illustrates some characteristic contact symbols and shows how the relay contacts are placed.

Examples of circuit diagrams and technical aspects are given in the following description of a point control and detection circuit.

The methods applied to control and to indicate points can, as is known, be divided into two main groups :—

(a) Control and indication *must* take place with different types of current, e.g. direct current for control and alternating current for indication. Moreover, the feed circuits for control and indication *must* be electrically quite separate.

(b) Control and indication *may*, if desired, take place by the same type of current. The feed circuits for control and indication *must not* be electrically separated.

Groups " a " and " b " are both employed in Denmark, but with the introduction of relay interlockings, group "b," *fig. 14, has been standardised for the following reasons.

1. In case " b " the number of conductors per switch is only 4, while for " a " it is 6 to 8 on the average. The expenditure on cables is considerably less than it is for system " a."

2. In system " b " it is relatively simple to prevent false feed and false indication.

Figs. 15 and 16 illustrate two typical cases of point control and indication circuits previously used in Denmark, which—despite the precautions taken—did not offer the necessary security against false feed.

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* See Inset Sheet No. 8

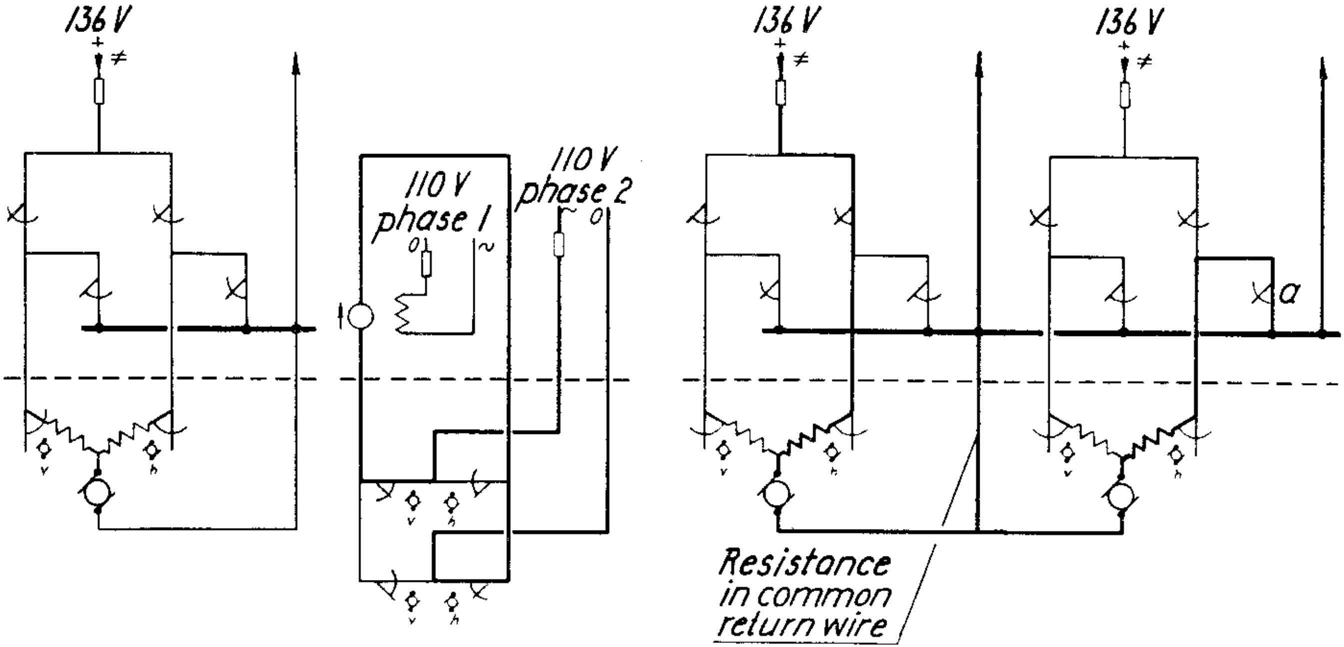

Fig. 15 Unsafe Point Control and Indication circuit (Control and Indication separate). Normal condition of circuit is shown at left. Contact "a" was introduced for the sole purpose of short-circuiting the motor when at rest. The resistance in the common return wire causes a voltage drop across the "short-circuited" motor when points outside the set-up route are operated, and this may result in untimely movement of points which are supposed to be locked.

The Danish State Railways use 220 volts d.c. (from a rectifier) for point control and 34 volts d.c. from an accumulator battery for indication. The design of the circuit diagram is based on the following theoretical considerations :—

The *first defect* to occur (false feed, false earth return, a relay which fails to drop away, etc.) must in no case result in untimely movement or untimely indication of the switch. The defect must, if dangerous, be revealed instantly through failing indication.

It may remain unrevealed, provided that a *second, simultaneously occurring defect* in no case results in untimely movement or untimely indication of the switch.

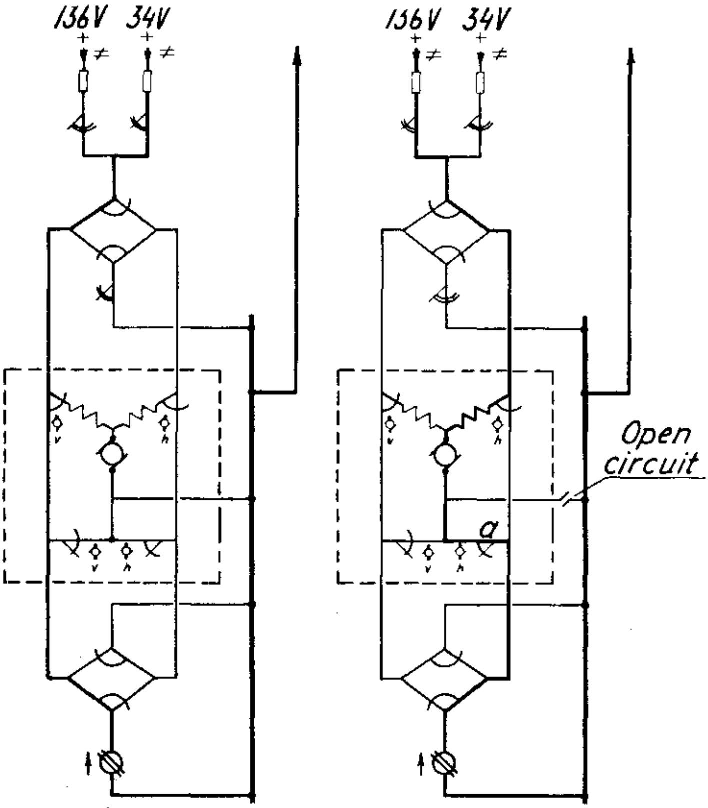

Fig. 16 Unsafe Point Control and Indication Circuit (Control and Indication interlaced). Normal condition of circuit is shown at left. Contact "a" was introduced for the sole purpose of short-circuiting the Indication Magnet while the points are under way. An open-circuit at the place shown will cause the Indication Magnet to be energised from the motor feed immediately the control lever is reversed, although the points have not moved.

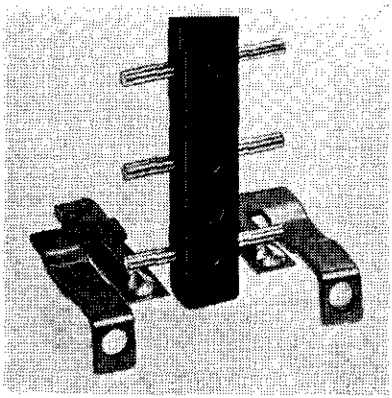

Fig. 17 A single Relay Contact with two silver-to-silver contact points in series.

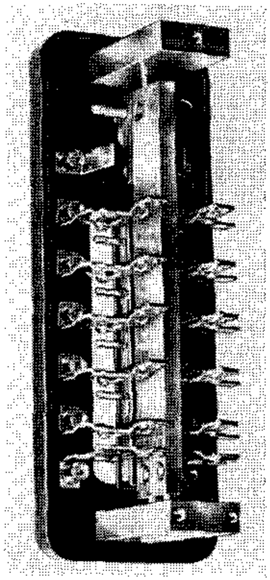

Fig. 18 Contact System for Relay with six contacts.

The second defect must, if dangerous, be revealed instantly through failing indication.

It may remain unrevealed, provided that a *third, simultaneously occurring defect* in no case results in untimely movement or untimely indication of the switch, etc., etc. (*ad infinitum*)

The standardised circuit, furthermore, contains the following characteristic details :—

1. The same individual push-button is used for both directions of movement.
2. To ensure that the staff does not operate the switch by mistake (some object may inadvertently be put over the push-button), a push-button common to several switches must be operated together with the individual button of the switch in question.
3. If the switch does not attain its new end position within 15 seconds, the feed is cut automatically.

From fig. 14 it will be seen that the cable conductors change polarity during each cycle of operation, so that all possible forms of false feed will result in blowing of a fuse and not in untimely movement or indication.

Safety Relays

The Danish State Railways have previously employed nearly all available types of relays in their installations. Experience thus gained came in useful when the essential properties of magnet and contact systems for relays in all-relay interlockings came up for discussion.

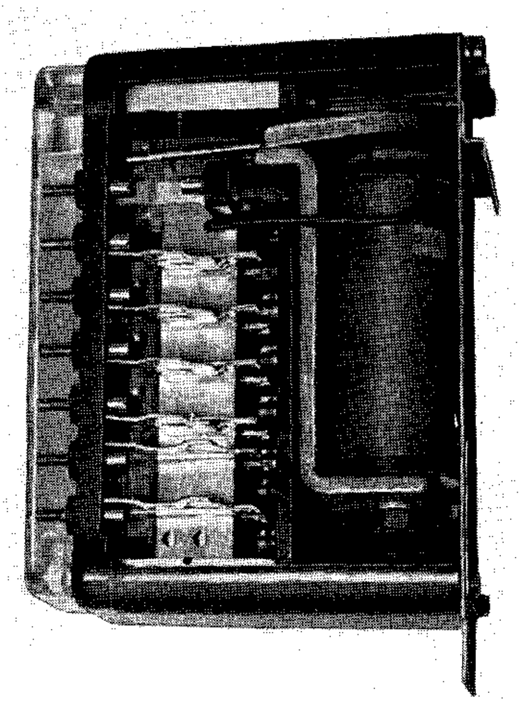

Fig. 19 Section through Relay with six contacts. Note absence of Armature bearings.

DECISIONS ARRIVED AT WERE:	FOR THE FOLLOWING REASONS:
1. Not to employ plug-in relays, but to use dust-proof enclosed relays with screw terminals.	It was considered possible to manufacture relays which could work reliably for a period of 15 to 20 years without inspection, and it was therefore considered unnecessary to use plug-in relays.
2. To employ silver against silver as contact substance.	More than 15 years of satisfactory experience in the use of silver as contact substance in safety relays.

DECISIONS ARRIVED AT WERE:	FOR THE FOLLOWING REASONS:
3. To use two contact points in series for each contact (figs. 17 and 18)	The safe rupturing current (and thus the durability of the contact) is greatly increased, and chances of dangerous faults resulting from fusion in the contact are considerably reduced. It should be emphasised that fusion of a contact has never occurred except in the laboratory.
4. To adjust the magnet and contact systems so that rebounding of the contact is avoided.	Arcing at the contact becomes almost negligible.
5. To fit most of the relays with relatively small magnet systems (watt consumption for attraction approximately 0.5). Only track relays and a few special relays have a larger magnet system (watt consumption for attraction 0.04).	The relays become quick-acting, which is as a rule technically desirable. At the same time arcing at the contacts is reduced.
6. The armatures do not rest in actual bearings (fig. 19).	Several of the defects that arose in relay types previously employed were due to faulty support of the armature.
7. Not to use actual plug-in relay groups.	Examination proved that there were no particular advantages in using relay groups in the comparatively small interlockings usually employed in Denmark (for instance, hardly any locked shunting routes). In the design of the latest type of relay, shown on fig. 20, possible application in relay-groups has been considered, and these relays (with a maximum of 8 contacts) have therefore been fitted with soldering terminals.

If the relay question were taken up today for renewed consideration, the result would have been the same as it was then, except that relay groups would undoubtedly have been introduced.

Five years have elapsed since the aforementioned decisions were made, and more than ten thousand relays are now in use. Experience has proved that the anticipated reliability has been obtained for a large majority of relay types (figs. 21 and 22).

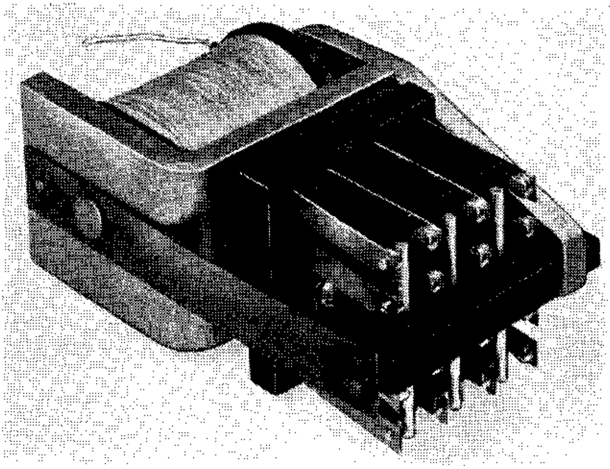

Fig. 20 Miniature Relay for use in Relay Groups.

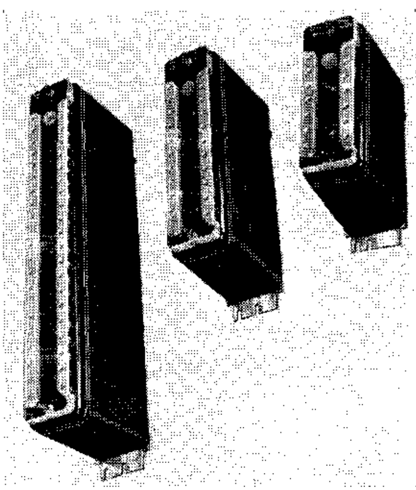

Fig. 21 Safety Relays with 20, 10 and 6 contacts. Note slotted Code Strip which ensures that only relays with the correct combination of contacts will fit in the corresponding space in the rack.

Control Panel

The arrangement of the control panel for all-relay interlockings has been one of the most difficult problems to solve. The Danish State Railways with the aid of the new equipment have sought, partly to improve the working conditions of the operating staff and partly to reduce the staff.

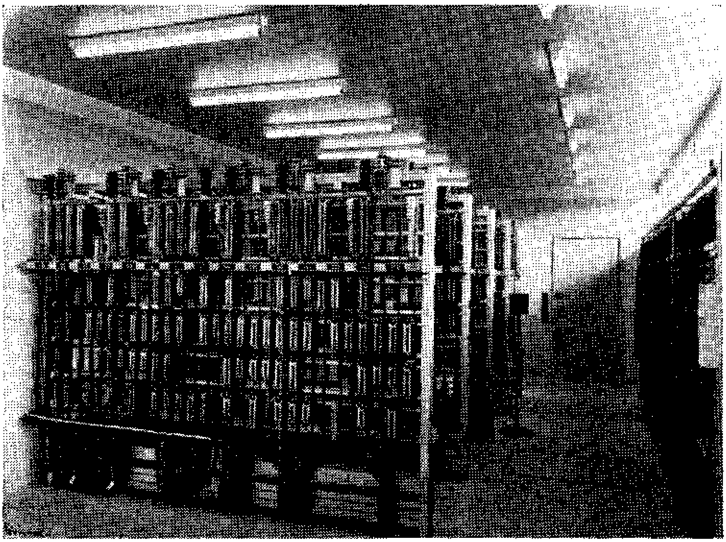

Fig. 22 Relay Room of Large All-Relay Interlocking (Odense). The Relay Racks are 2·75 metres long and have relays both on front and back.

The control panel had, therefore, to be made as small as possible, besides which the manipulation should be logical and simple. In designing the panel, due consideration had to be taken of possible track alterations, which should not necessitate scrapping of the whole panel.

The latest control panel for all-relay interlockings is recognisable by the fact that the push-buttons for control of switches, routes, signals, etc., are all placed on the track diagram (figs. 23 to 25), which also contains repeating lamps showing :— electrically controlled points, hand-operated points, whether track circuits are occupied or free, set-up routes, position of signals, condition of lock-and-block system on the adjoining stretches of line, day or night voltage on colour-light signals, etc.

The control buttons are usually placed so close to the symbol of the object to which they correspond that one can hardly avoid seeing the repeating lamps that are placed in or near the symbol to guide the staff in deciding when it will be correct and expedient to take action. The buttons are all two-position press-buttons, and the manipulations are of quite short duration (usually less than a second).

Fig. 23 Control Panel at Odense.

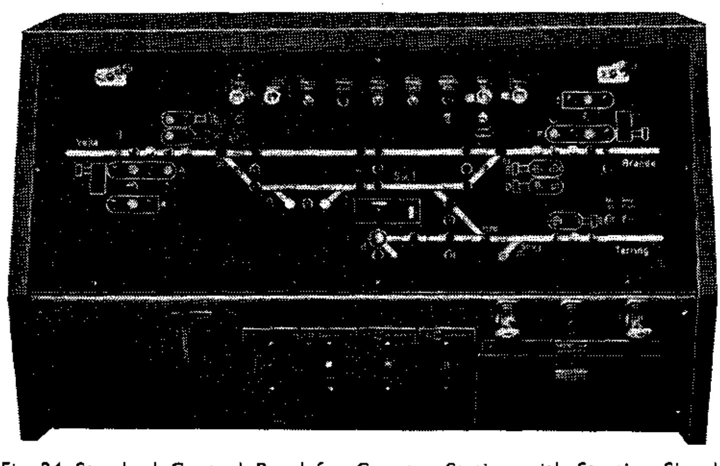

Fig. 24 Standard Control Panel for Country Station with Starting Signals on Single-Track Secondary Main Line.

The basic element of the track diagram is a perforated metal sheet, figs. 26 and 27, on which the push-buttons and the sockets of the repeating lamps are fitted by means of intermediate fixing pieces, the flour flaps of which can be bent so that the holders are firmly fixed in the holes in the perforated sheet. The buttons, whose contact system is enclosed, have only one contact (a non-independent make-and-break contact). Both locking and non-locking buttons are used, and the various types are differently coloured and engraved.

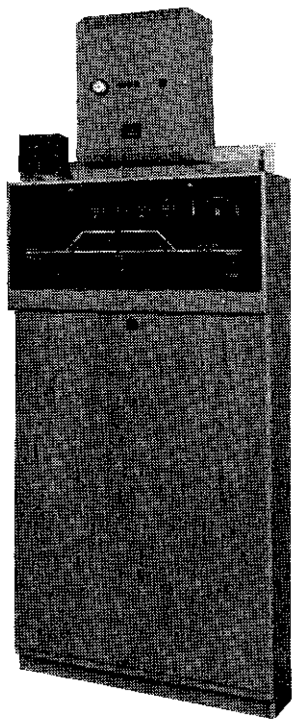

Fig. 25 Standard Combined Control Panel and Relay Cabinet for Country Station without Starting Signals on Single-Track Branch Line.

The lamp sockets can be fitted with transparent symbols of different shapes and with filters of different colours.

The perforated sheet is covered by the actual track diagram, on which a schematic representation of running tracks, etc., is engraved. In large installations the engraved diagram is divided to enable track alterations to be made more easily.

There are two types of installation :—

D.S.B. 1953, mentioned below, which is employed in large interlockings, and

D.S.B. 1954, which is employed in other installations.

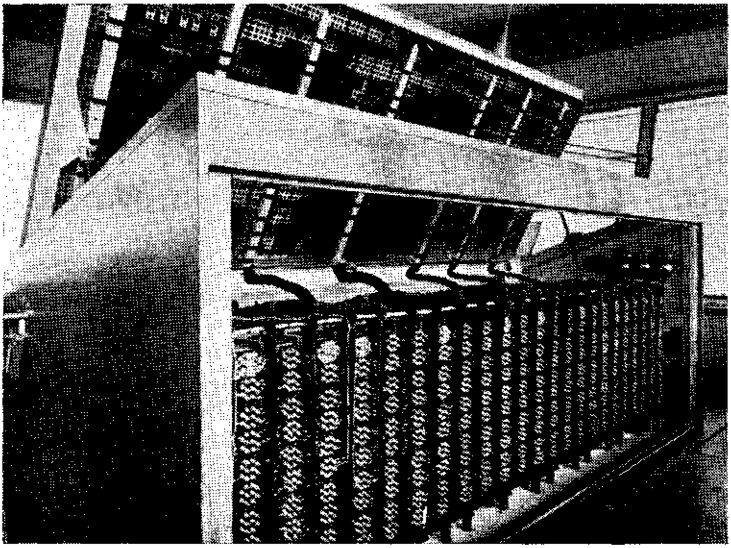

Fig. 26 Rear View of Control Panel at Odense.

Electrically Controlled Switches

A switch is operated by pressing an *individual button* (black) on the symbol of the switch as well as the *common button* (black, engraved with the letter F), which is common for a group of switches. The necessity of having to manipulate two buttons eliminates the possibility of the switch being operated inadvertently by touching one button. That the switch has begun to move is registered, partly by extinction of the indicating lamp for the former position of the switch, and partly by a single bell-stroke. Furthermore, the indicating lamp for the new position of the switch shows flashing white light. Completion of the movement is marked by a new bell-stroke, and the indicating lamp for the new switch position now shows steady white light. Moreover, movement of the switch is indicated on an ammeter or an indicating lamp on the track diagram. The same individual button is used for both directions of movement of the switch.

For each switch, another indicating lamp is provided which is capable of showing either red or white light. This symbol is normally dark, but the *red* light is lit when the track-circuit through the switch is occupied, and no attempt must be made to operate the switch before the track-circuit is clear again (track-circuit symbol dark). The *white* light is lit when a route which includes the switch is locked, and the lamp then at the same time indicates that the switch cannot be moved, and that the track circuit through the switch is unoccupied.

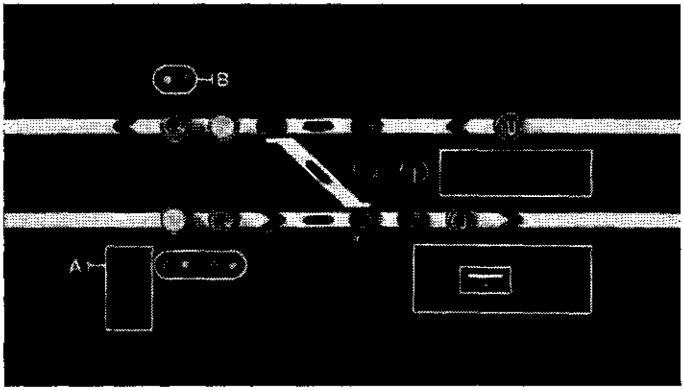

Fig. 27 Close-ups of Control Panel. (a) Front view.

Main Train Routes

A train route cannot be set up before the switches are in the correct position. The route is locked and the signal cleared by the simultaneous pressing of a signal button (yellow) in the track symbol adjacent to the signal in question and of a route button (green engraved with I or U) in the running-track in question. The locking of the route is indicated by white light in the track sections concerned, provided the corresponding track circuits are unoccupied (occupied sections show red light). The relay system actuated by the push-buttons tests, automatically, whether all the track circuits in the route are unoccupied, and if this is the case the signal is cleared, which can be seen from the repeating lamps for the signal in question.

Route-locking and clearing of signals are also indicated by two arrow-shaped repeating lamps in the track: white light in the arrow next to the route button (route locked), and yellow light in the arrow beside the signal button (signal cleared).

Automatic route-release is provided.

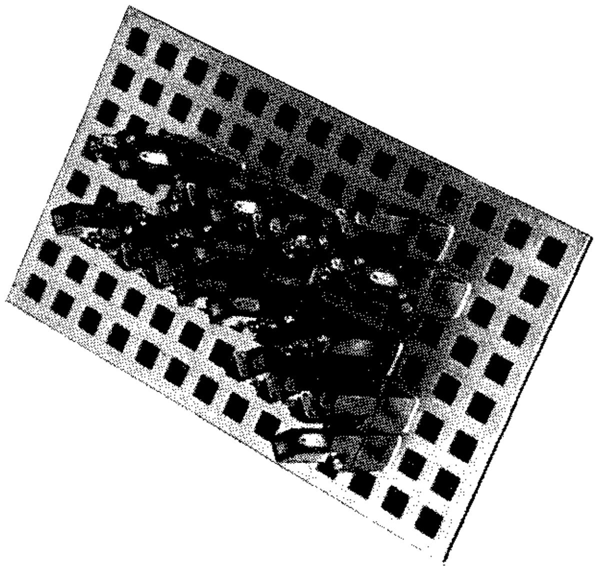

Fig. 27 Close-ups of Control Panel.
(b) Rear view, showing perforated baseplate and arrangement of lamp sockets and push-buttons.

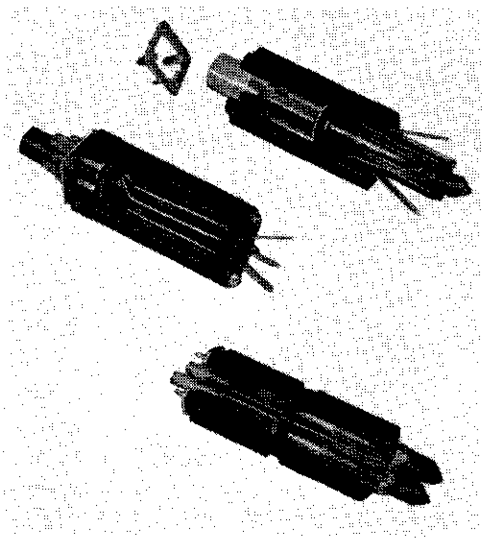

Fig. 27 Close-ups of Control Panel.
(c) Section through single and twin lamp sockets and push-button, and intermediate fixing piece.

For trains *arriving* from lines *without* automatic block, the signalman must, however, first press the stop button (red) belonging to the signal in question to indicate that the tail signal has been observed. In such cases, releasing of the route is registered by flashing light in the yellow arrow beside the signal button. The arrow is extinguished when the button is pressed.

Supply of Current

In electric interlockings of an earlier date, battery reserves were always available partly for actuating all the relays and partly for the switch and signal motors. Development after the war of reliable small petrol engines has made it possible for such engines to be advantageously used in connection with large or particularly important interlockings. Now battery reserve is only provided for the relays, the battery at the same time serving the purpose of starting battery for the petrol engine. This is installed in the open air, only protected by an ordinary motor-helm ; it produces alternating current which is used for signal lamps, track circuits, etc.

The accumulator battery is trickle-charged from an automatic rectifier that regulates the charging current according to the needs of the battery.

Automatic Block System

Only a few short stretches of line were equipped with automatic block in Denmark before the war ; now automatic block is being installed on a comparatively great scale. A system has been chosen, the security of which is based partly on actuation of a short (45-60 m.) track circuit immediately in advance of each stop signal, and partly on a long track circuit (the length of the block section less the short track circuit). The long track circuit is used to establish the necessary rotational locking between the successive block signals. Three-position track relays are employed, whose position is determined by the polarity of the track feed. Current codes are sent from the feed end (leaving end) to the relay end (entering end) which indicate the passage of the train over the short track circuit, and prove that the signal at the leaving end has returned to the danger position.

Two-element three-position a.c. track relays are used in the d.c. electrified Copenhagen suburban area, whereas in other cases polarised three-position d.c. track relays in conjunction with a non-polarised d.c. relay are used. So far as the latter track relays are concerned, the total energy consumption of the two d.c. relays amounts to 100 milliwatts. With such double relays, automatic block systems with sections up to 8 km. in length are being planned. The very low drop-away shunt inherent in long track circuits (0·08 ohm for 8 km.) is considered permissible on account of the double safety precautions described above.

The feed for the long d.c. track circuits is taken from a rectifier with yielding output voltage, which can feed a track up to 8 km. in length when the ballast resistance is at its lowest, while the output voltage drops to a very low value when the track circuit is occupied. As emergency supply, lead accumulators are employed.

The two-element three-position a.c. track relays are provided with a squirrel-cage motor, the rotor of which consists of an iron cylinder sprinkled with a thin layer of copper. This motor has proved to be superior to and more effective than rotors of a more complicated nature (and far cheaper).

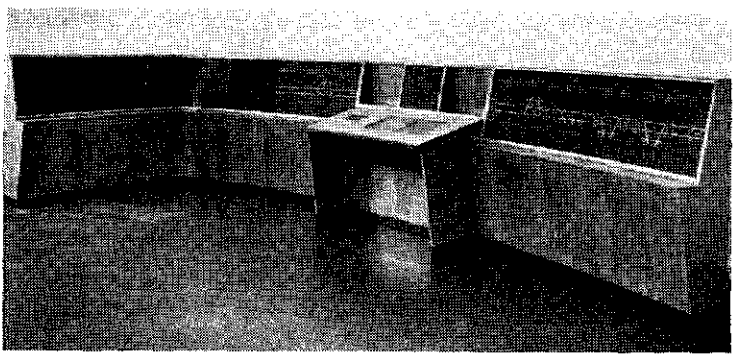

Fig. 28 C.T.C. Control Panel for Nyborg-Fredericia Main Line.

Point Machines

Danish point machines have the following characteristic properties :—

1. The machines are trailable, and the holding force which the wheel flanges must overcome when trailing is for safety reasons required to be at least 100 kg. over the force applied to the switch blades during normal operation, the latter force to be 350 kg. plus or minus 10%.

2. All machines are provided with two detector rods, one for each switch blade.
3. A trailable facing-point lock is provided either in the point machine or in the actual points. Probably the former type will be used exclusively in the future.
4. Attempts are being made to design a machine that can also be manipulated by a hand-lever on the machine.

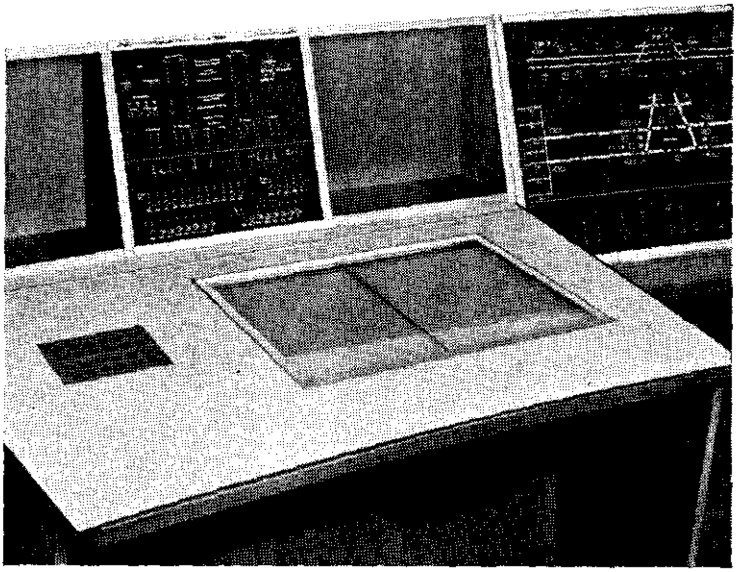

Fig. 29 C.T.C. Control Panel, close-up of central portion, showing panel section with control and indication equipment common to the whole line, besides Operator's Desk with built-in Train Recorder and Push-Buttons for Telephone Switchboard and for inserting Train Type Indications on panel.

Centralised Traffic Control (C.T.C.)

Figs. 28 and 29. Remote control of small country stations has lately become of importance to the Danish State Railways because of the considerable decline in goods and passenger traffic at such stations, and because staff expenditure for train dispatching is considerable.

The Danish remote control systems now being installed have the following main characteristics :—

1. Selectors with rotating parts are not used.
2. Control and indication takes place over the same pair of line wires.

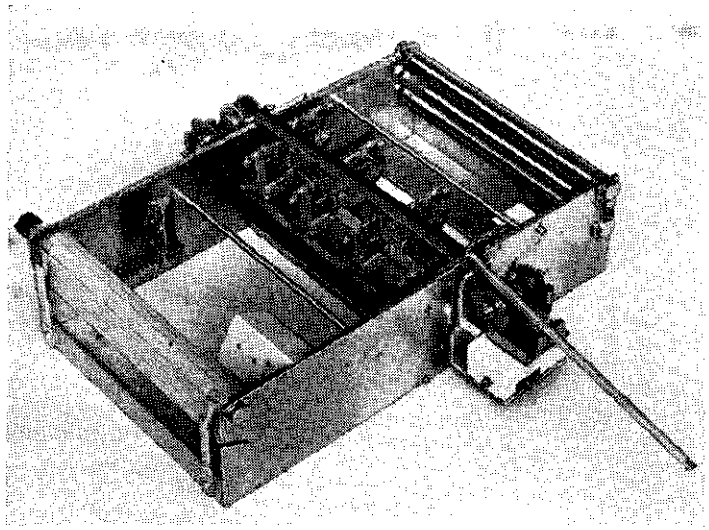

Fig. 30 Details of Train Recorder.
(a) Inside of Recorder. Only 8 hammer units are shown, but there is room for 56 units, corresponding to 112 hammers.

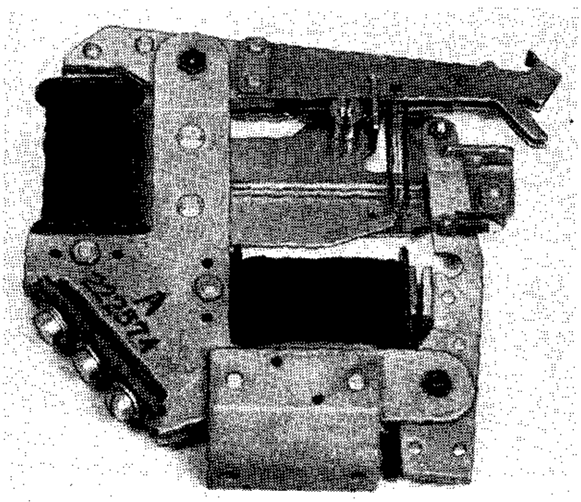

Fig. 30 Details of Train Recorder.
(b) Hammer unit, containing two hammers with separate actuating magnets.

3. The maximum capacity of the system is :—
   a. Choice of 36 remote location units ;
   b. 36 orders per such unit ; and
   c. 49 indications per unit.

   A station with passing track on a double-track line requires two remote location units.
4. Orders that cannot immediately be carried out are indicated as such even while the order is being given, so that the dispatcher need not wait in vain for the corresponding remote indication. It is also possible to store a certain number of orders.
5. The relays are mounted on uniform strips which are electrically connected with the rack by means of multiple-terminal plugs.
6. The indications that register the passage of the trains along the line and through the stations also actuate a train recorder. Registration is effected by electro-magnetic hammers and employs two colours corresponding to the two directions of running. The recording instrument draws a distinct graphic time-table on the chart, see fig. 30.

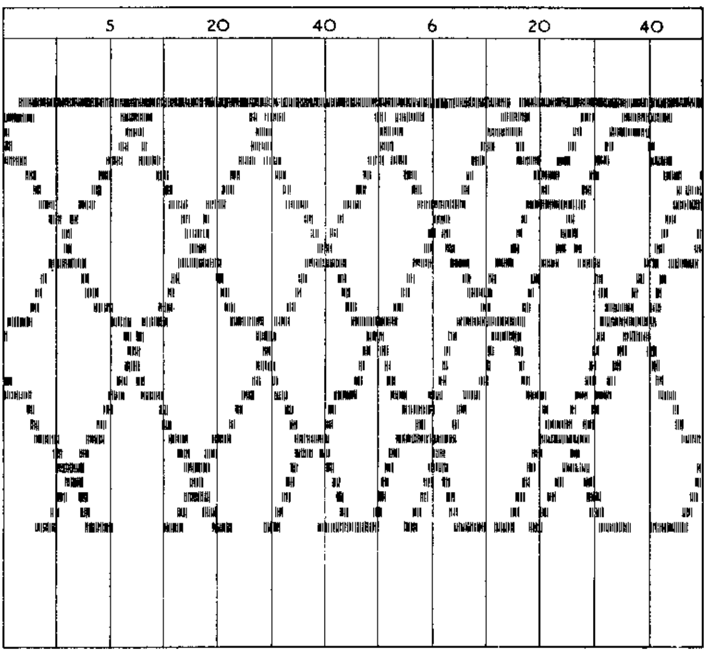

Fig. 30 Details of Train Recorder
(c) Recording Paper, showing how train movements are indicated. Different colours (red and blue) are used for the two directions of running.

7. Furthermore, on the control panel three classes of trains (fast, slow, and stopping) can be indicated. It is thus possible to follow the course of trains over the block sections and through the stations.
8. To every remote location unit an order can be given to send a complete new set of indications for the interlocking in question. On the control panel all the "old" indications involving safety considerations will first be cancelled.
9. At the remote station there is a box containing an emergency push-button by means of which, in case of emergency, all signals can be returned to danger at the same time ; furthermore, there is an emergency handle for the point machines, and when this is removed all signals return to danger and all point indications are cancelled.

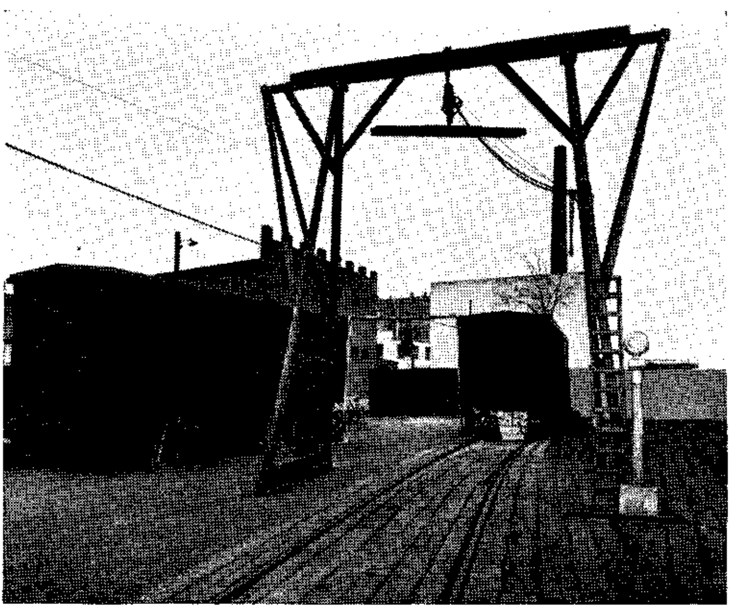

Fig. 31 Yard of D.S.B. Signal Workshop with Apparatus Huts for two remote-controlled stations. At right, a Warning Signboard with built-in Loud-speaker for the protection of passengers who must cross the track at remote-controlled stations.

10. Stations on the remote controlled sections usually have no subway or overline bridge for passengers. Protection is afforded the public by a revolving signboard which indicates

whether it is permitted or prohibited to cross the track (fig. 31, at right), and by a loud-speaker announcing " don't cross the track, a train is approaching."

Fig. 31 further shows the apparatus huts for two remote-controlled stations, each hut containing relay racks for telephone, remote control and signalling equipment, besides an accumulator battery. The equipment is assembled and fully tested in the workshop, and the complete hut, weighing about 15 tons, is transported by rail direct to its permanent site.

Protection of Level-Crossings

On Danish branch lines, the number of unguarded level-crossings is very great, so that the problem of adequate protection of these is of considerable magnitude. At the present date (September 1st, 1956), 1,042 road crossings in Denmark are protected by automatic (train-operated) signals which show flashing red light to road traffic and flashing lunar-white indication light to the driver of the approaching train ; 262 of these level crossings are on State Railway branch lines and the remainder on the numerous private secondary lines. Where the ruling speed on the railway is higher than 75 km.p.h., full barrier protection must be provided, and interests of economy now dictate that the

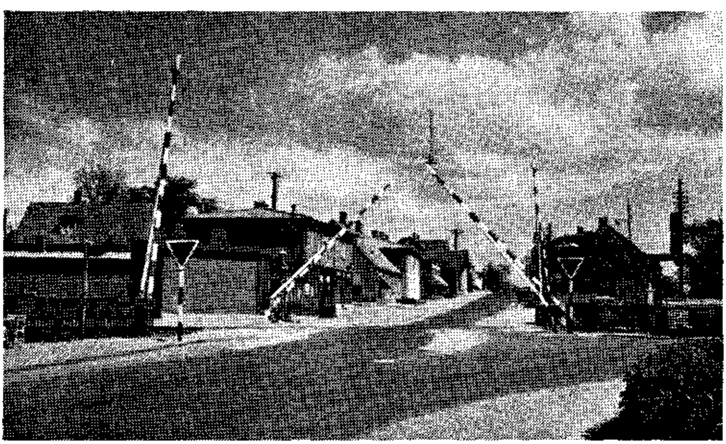

Fig. 32 Remote-controlled Double Half-Barriers with Warning Lights and Bell. All four barriers are descending, but the two which cover the right-hand half of the roadway have a start of 6 seconds.

barriers should, where possible, be automatic or at least remote-controlled in order that the level-crossing keeper may be dispensed with. To begin with, the State Railways in 1952-54 installed experimental half-barriers as a supplement to the existing warning lights at four busy level-crossings on a branch line in the Copenhagen area. This equipment has proved very satisfactory, and the number of half-barriers on branch lines is now 10 and is steadily increasing.

The first example of full barrier protection with modern equipment is the remote-controlled installation shown on fig. 32, consisting of double half-barriers supplemented by warning lights and single-stroke bells. The sequence of operation, which is automatic when once started, is as follows :—(1) Warning lights and warning bell in action for 6 seconds ; (2) The half-barriers across the right-hand side of the roadway begin to descend ; (3) After a further 6 seconds to give passing road traffic time to clear the track, the two other half-barriers begin to close (this is the situation shown on the photograph) ; (4) When all four half-barriers are closed, the bell ceases to ring, but the warning lights continue to flash ; (5) When the train has cleared the roadway, the warning lights are extinguished, and all four half-barriers are raised simultaneously.

DISCUSSION

In opening the discussion the **President** said that although the authors had remarked that one should not expect too much from a small country such as Denmark he was sure that their papers had shown much that was of interest and members would learn a great deal from the technical descriptions that had been given.

Regarding plug-in relays, Denmark was quite close to the larger railway system of the German State Railways which, since the war, had developed a new technique in relay interlocking. This was becoming the line of thought in many continental countries and it was very interesting to see the results which had been achieved by the Danish State Railways. No doubt many members might not agree with some of the conclusions mentioned in the paper

Mr Wessel Hansen had said that their relays were constructed to last twenty years, but the life of a relay depended to a great extent on the density of the traffic system on which it was used.

He thought that Denmark could be very proud of the fact that they had shown the courage and foresight to adopt centralised traffic control not only in the conventional way applied to single track, but also to double line territory.

The highway crossing barriers were not new on the continent, but the power-worked half-barriers were relatively new there, and he thought that within a few years it might be decided that they would be of value on British Railways.

Mr. E. G. Brentnall said that he had had the privilege of inspecting a number of Danish signalling installations, and although Denmark was a small country, they had independence of thought and very progressive ideas. That became more apparent when one actually saw the installations. The fact that they had 52 relay interlockings was no small achievement, even allowing that some of them were not very large.

The question of speed indicators had been given a great deal of thought in countries where speed signalling was generally in use, and with that system one had to provide a limited number of speed indications and ensure that trains could proceed at those speeds. It could not be used with the unbraked stock in the United Kingdom but it was hoped that all trains would be fully braked in the course of a few years. More indications were necessary with speed signalling than with route signalling. They could be given with colour-light aspects, or with separate indications in the form of a figure, such as those used in Belgium, a " 4 " to indicate 40 kms. per hour, or, as used in Denmark, by a simplified geometrical figure, which were very clear at 500 yards when he observed them. During his visit the day was not very sunny and a fog came up from the harbour, but did not encompass the indicators, so he was unable to judge their visibility in foggy conditions. However, if the speed indicator could not be seen, the signal itself displayed the most restrictive aspect and therefore would be on the safety side.

The system used in Denmark and other countries such as Sweden, of the transfer of the control of points some distance away to ground operation was very interesting. It should be emphasised that in most cases they were power operated, and when divorced from the signal cabin, were operated electrically by push button from the ground. At present all mechanical points and electrical points were trailable, but as the trailability feature meant additional apparatus, he wondered if, in future, they might consider certain points being non-trailable, when shunt signals were installed.

Regarding the point circuit system in which the current is cut off after 15 seconds: Mr. Brentnall enquired as to what was the next stage if the points had not moved. Was it possible to go back to the original position of the lever and try again, or was it necessary to call upon the maintenance staff.

He expressed great interest in the sample relay which was before the meeting for inspection, and said its small size and constructional detail merited very careful thought and consideration. Mr. Brentnall said that he would like to have more details concerning the 8 kms. long track circuit.

Lifting barriers were in general use on the continent and recently he had seen a number of them in company with Colonel McMullen and other officers of the Ministry of Transport. There were flashing lights at crossings with half-barriers or without barriers, and no signal was provided along the railway for trains. In Holland, a small aspect was shown so that if the flashing light were out, the driver could report it, and he enquired if the flashing lunar white light along the rail described in the paper was for that purpose. He understood that if the flashing red light should fail, a continuous yellow was shown. He said he would like to know the author's view on half-barriers automatically operated by track circuits or treadles, as against those operated remotely.

Mr. H. J. N. Riddle asked whether the development of signalling technique and the design of apparatus were carried out solely by the Danish State Railways, or if the manufacturers had helped in that respect.

Mr. T. S. Lascelles said that he had never visited Denmark but through the kindness of Mr. Steffensen had received a number of publications over a long period, illustrating the old fashioned apparatus in the country and their modern progress.

With reference to the lock-and-block working, he enquired if it were intended to extend the Siemens' standard system, or to devise something else for the new kind of working. He also asked if mechanical signals were lighted by acetylene gas, as was the practice in Sweden, or by propane gas, which had been introduced in some parts of the continent.

He was interested to learn how long ago a yellow light was adopted in Denmark for distant signals. He believed it had been in use for a long time, but asked what was the practice before then.

In examining the signal diagrams, he had wondered why in multi-aspect signals, a yellow light was not used, but only red, green, and flashing green. He noted that the steady green and the flashing green were used differently to what they were in Sweden, where flashing green acted as a warning.

As regards the cancelled aspect in the ground signal or starting signal, he assumed that when this was exhibited, the driver obtained orders from the shunters only. (*The Author replied that this was correct*).

The trailability of points had attracted attention in the United Kingdom for some time. After trailing through the points were clipped, and he asked how long the clipping remained in force and under what circumstances it was removed. He had been informed by Mr. Hård, the Signal Engineer of the Swedish State Railways, that although they adopted shunting signals for every move, they still considered trailability was advantageous because it limited the possibility of damage due to a run-through. He asked if that view was upheld in Denmark.

In regard to mechanical installations, he enquired if the double wire system was generally compensated as in Germany, or if in Denmark they worked without compensators as much as possible.

In the diagram of point control, he assumed that relay **5** (square coil) corresponded to the Siemens and other systems' switch, which, when a pair of points were reversed, jumped back when the indication was received. (*The Author replied that this was correct.*)

Mr. Lascelles said it was very interesting to see what had been done with relay construction and one could not but admire the engineering ability that had been put into those items and the technique which had been followed.

Regarding the centralised control sections, he asked if thought had been given to the introduction of reversing working generally as had been adopted in Sweden. He thought there might not be the same incentive, because the object in Sweden was to enable the track to be free for transmission from overhead wires.

Mr. A. Cardani asked why starting signals were now always fitted with signal replacers, and also wished to know whether in Denmark they had given any thought to what was known in Great Britain as sequential locking.

Referring to C.T.C. installations, he asked how long it took for an order to be dispatched, completed and the indication to be returned. He noted the very low train shunt on the 8 kms. long track circuit and wished to know whether the same train shunt worked on short track circuits or whether it was higher.

With regard to double half-barriers, he asked if it were intended to keep them a sufficient distance from the track so that a vehicle trapped on the crossing could draw clear.

Mr. L. W. H. Lowther noted that the paper stated that selectors with rotating parts were not used for centralised traffic control, and he enquired what type of relay was employed. The maximum capacity of the system was given as 36 remote location units, 36 orders për unit and 49 indications per unit, and he wondered whether any difficulty was experienced with regard to the jamming of the two line wires, and whether the indications were slow in coming in.

Colonel D. McMullen pointed out that, instead of saying that British Railways were not allowed by the Ministry of Transport to have half-barriers, it would be more true to say that half-barriers were not allowed by Parliament.

He had recently returned from a visit to the Continent in company with Mr. Brentnall and their main study had been the level-crossing problem. They had been very interested in what they saw there and to hear what was done in Denmark. He asked if the double half-barriers described in the paper as working by remote control were in some cases operated automatically.

Mr. L. P. Boucher asked whether C.T.C. was used on double line track and whether there had been any experience of jamming of the control codes being sent out, when there was a large number of indication codes coming back. Also, what was the nature of the headway they were able to signal through by using ordinary line wire and a single code, without experiencing jamming.

After a brief consultation between the authors, **Mr. Steffensen** replied on behalf of them both. He said that they intended to retain the trailability of points, which they considered to be a valuable feature. When a set of points did not reach their new position after fifteen seconds, they returned to the original position. In fact, the circuits were so designed that if an operator began to move the points, they could be reversed immediately should it be necessary to do so.

The long track circuit was still in the course of development.

Indication lights were different at crossings which had flashing lights only and those which had barriers or double half-barriers. At a crossing with flashing lights only, when the flashing lights were not in operation, no indication light was shown to the driver. Only when all the red lights were in action towards the road, was the flashing white light shown to the driver of an approaching train, who had a special sign board which told him that an indication signal would follow 100 yards ahead. If he did not see the indication light, he must attempt to bring the train to a stand at the crossing and must sound his whistle continuously to allow him to proceed slowly over the crossing and report to the first station that there was something wrong. Where there were barriers at a crossing, then normally there was a steady yellow light against the train when the barriers were open to the road traffic; but when all the red lights were flashing towards the road and all the barriers had begun to descend, whether all four or two, an indication light was shown to the driver. It would perhaps be more correct not to show the indication light until all four barriers had actually closed, but once they had started, the possibility that they would not finish was exceedingly remote. Therefore, they could show an indication light to the driver ten seconds earlier than otherwise.

Regarding the operation of barriers, they could be either automatic or remotely controlled. In the installation which Mr. Brentnall saw, when a train standing at the station was about to depart, the barriers were started by hand by the station staff or by the guard of the train. Trains which passed without stopping and those coming from the other side actuated a treadle and caused the barrier to descend automatically. Automatic barriers were used on main lines.

Development work was now carried out by the State Railways as regards actual interlocking and safety circuits, but in the case of C.T.C., the remote control portion was developed by industry and submitted for approval to the State Railways.

They did not propose to install any more block working of the Siemens type. The Siemens block was very satisfactory when originally introduced, and at that time there were no a.c. power mains. Recently, they had experienced a number of unexplained false clearances of block sections, probably due to false currents from a.c. mains. A.C. block instruments depended upon correct operation and there were various possibilities of making mistakes in handling the apparatus. When a mistake had been made, one could get locked and unable to clear a signal and misunderstandings were liable to arise between stations and between drivers and stations. There had been one or two serious accidents caused by irregular block working.

They only used acetylene gas for the lighting of the mechanically operated semaphore distant signals. The supply lasted for about three months, when the container had to be renewed.

In stop signals, a steady yellow light was not used alone for fear of confusion with the numerous yellowish lights outside railway premises, but red over yellow was shown from home signals with starting distant. The flashing green light was only used on electrified lines in the Copenhagen area; on the tunnel sections two green lights could not be used because a minimum distance of 1·5 metres is enforced between lights belonging to the same aspect. The green light in Denmark corresponded to the British yellow light, and two green lights or one flashing green light corresponded to one green light in Britain.

When a pair of points had been trailed and inspected by the station staff and found safe to traverse, they must be clipped before being traversed in a facing direction. After the permanent way staff and the signal lineman had both made an investigation and found the points to be in order, normal working could be resumed.

In mechanical installations, the double wire system was compensated, as in Germany.

On double-track C.T.C. sections, both tracks were signalled for reversible working, but for trains taking the wrong track there was only one block section between neighbouring stations. Wrong-line routes were only provided from the passing track at one station to the passing track at the next station. As the passing tracks were common to trains in both directions, they had always track connections to both running tracks at both ends of the station, so that wrong-line working could be provided without putting in extra crossovers.

Signal replacers were used because they could have two trains standing ready to start in the same direction from the same track, and as they had sequential locking between the home and the starting signal there was no risk of sending off a train on a starting signal which was intended for a preceding train.

Answering the question on the time required for orders and indications on the C.T.C. system, **Mr. I. Boberg** stated that the time for one control would be about one second and the time for one indication would also be one second. If there were many indications about the same time, the total time for all the 49 indications would be about 4 seconds.

Continuing, **Mr. Steffensen** said they had a much higher train shunt for a short track circuit than for the 8 km. long section, but they did not consider it necessary to have a high train shunt on the long section because they could not clear an automatic signal unless they sent the code through the long track circuit from the leading end. The code was transmitted when the train cleared the short track circuit at the leading end. If they should lose the shunt on the long track circuit whilst a train was in transit the signal would not clear.

Regarding the question as to whether room was allowed for a car between the crossing-barrier and the track, there had not been room hitherto, but there would be with all new installations.

Ordinary telephone-type relays were used instead of rotary selectors on the C.T.C. system. Regarding the time taken to send all the indications, he did not anticipate any jamming of the line wires. They had not had any experience in that respect yet, because they had only two remotely controlled stations against twelve, when completed.

The remainder of the questions would be answered by post.

The **President** extended to Mr. Steffensen and Mr. Wessel Hansen the grateful thanks of all the members for their excellent paper, which was of great interest, and expressed the hope that they would return on some future occasion. He proposed a hearty vote of thanks to the authors, which was carried with applause.

The Authors communicated the following answers :

Yellow Light in Distant Signals

The Danish distant signal was originally a round disc which showed full disc or green light in the caution position and edge of disc or white light in the clear position.

A similar disc signal was used as a point indicator for siding connections, the clear aspect being shown when the points were set for the running track, irrespective of whether this were straight or diverging. In trap points, the green light of the caution position was replaced by violet light. In 1930, the meaning was changed so that the caution position always corresponded to the diverging track, and discs were no longer to be used for trap points. Disc point indicators can still be found on Danish private lines; the green light of the caution aspect persists, but will shortly be replaced by orange light.

The low semaphore distants with fish-tail arm, which replaced the disc distants in 1903, have always shown orange light for caution and green light for clear. From 1922 onwards, the steady light was replaced by flashing light; the change-over was carried out systematically on all main lines of the State Railways, but the steady light in distant signals on branch lines was not finally abolished until 1935.

Signalling Practice on the Danish State Railways *(Steffensen and Wessel Hansen)*

(a) Points indicated normal.

(b) Individual and Common Buttons operated. Demagnetising Current applied to Relay 6.

(c) Normal Indicating Relay 4 de-energised, Relay 10 and Battery Change-over Relay 5 energised. Timing Condenser for Relay 2 is being charged.

(d) Control Relay 7 Magnetised and Timing Relay 1 energised. First Point Machine under way.

(e) Movement of both Point Machines completed, Points indicated Reverse.

Fig. 14 D.S.B. Standard Point Control and Indication Circuit for All-Relay Interlockings (Coupled Points)