ERICSSON REVIEW

RAILWAY SIGNALLING SYSTEMS
CONSTRUCTION PRACTICE BYB FOR TRANSMISSION EQUIPMENTS
FIRST-ORDER PCM MULTIPLEX IN THE BYB CONSTRUCTION PRACTICE
AXE 10—A REVIEW
OPERATION AND MAINTENANCE FUNCTIONS IN ASB 100 AND ASB 900
ANTENNA SYSTEM FOR THE EXOSAT SATELLITE
A TELEPHONE SYSTEM FOR FOREIGN EXCHANGE TRADING
CUSTOM DESIGN CIRCUITS FOR TELECOMMUNICATIONS

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COVER
The signal to the left in the cover picture symbolizes modern railway signalling technology

Railway Signalling Systems

Hans S. Andersson

The Ericsson Group have designed, manufactured and marketed railway signalling equipment since 1915. The product range has included such systems as signalling equipment for the track, safety systems for the train routing, remote control systems and systems for supervising the speed. The product range has successively been renewed in step with the technical development. The development in the fields of electronics and computers has contributed greatly to this renewal. This article deals with the background and the present scope of this work. Some of the recently developed systems will be described in greater detail in subsequent issues of the magazine.

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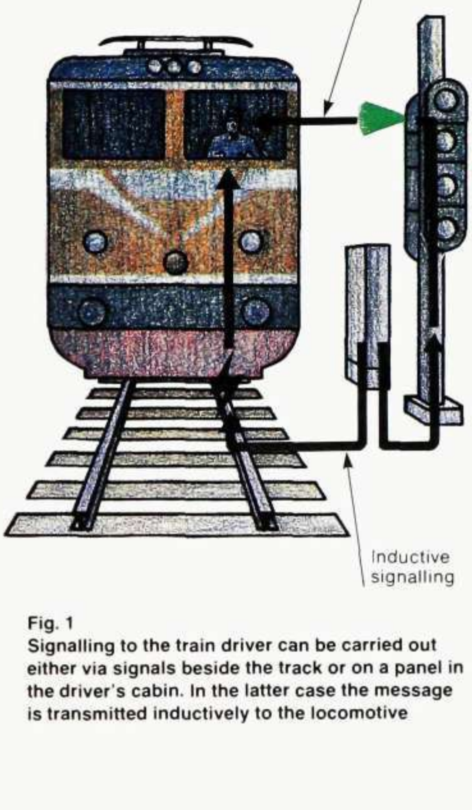

Fig. 1
Signalling to the train driver can be carried out either via signals beside the track or on a panel in the driver's cabin. In the latter case the message is transmitted inductively to the locomotive

The railway administrations are constantly seeking ways and means of utilizing the tracks, rolling stock and personnel more efficiently without any reduction in safety. Rail traffic poses very special safety problems. The high speed and high mass of the trains in combination with the low friction between steel wheels and rails give considerable braking distances. Rigorous rules must be set in order to safeguard against traffic accidents. The aid and devices that help to achieve this safety and efficiency are used to

- set up train routes, control points and signals, ensure that the track is free and safeguard the movements of trains
- transmit information to the train driver
- supervise the speed.

In modern signalling systems the operation of points in order to prepare train routes and to provide protection against conflicting train movements is almost exclusively done with remotely controlled, electrical point machines, fig. 4. However, manual operation of hand-thrown points occurs on track sections that are seldom used.

A detection device, called a track circuit, is used to check that the track is free from trains and vehicles.

The established train route is protected against conflicting train movements by interlockings. The interlocking conditions state that points in the routes cannot be switched and that conflicting signals cannot be cleared.

The interlocking equipment, which is usually common for a whole station or yard, is normally placed fairly close to the objects, such as points, tracks and signals, that are to be supervised. The control equipment can be placed at a greater distance. Thus the control can be centralized to a few places, fig. 2. Such systems contribute to efficient traffic handling and low personnel requirement.

The information to the train driver is transmitted by means of fixed signs and light signals. Information to the locomotive can also be transmitted inductively from special transponders on the track or via radio, figs. 1 and 5.

Fig. 2
Train movements in stations can be controlled locally or centrally. In the latter case a large number of stations are controlled from the same place, i.e. centralized train control, CTC. The picture shows the local control office in Oslo central station, Norway

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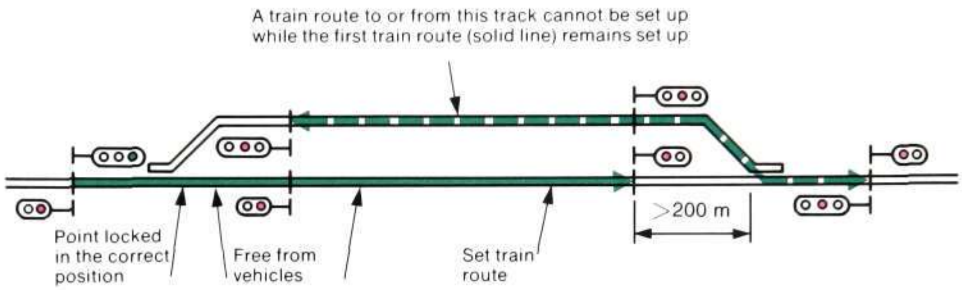


Fig. 3
Certain conditions have to be met to safeguard the movement of a train at a station

Supervisory equipment, which brakes the train if the driver keeps too high a speed, has long been used in underground systems and has also been introduced on certain railway sections, where trains run at a very high speed or where the traffic density is very high. On other sections with very little traffic it has previously not been possible to justify economically even the introduction of automatic braking if the train passes a stop signal. New technology now offers the possibility of speed supervision also on sections with low traffic density and in the long run it will be possible to relieve the train drivers of some of the responsibility they now bear, fig. 6.

Safeguarding of train movements

Train movements must be protected against
- collision with other trains
- collision with vehicles on level crossings
- derailment because of point changes at the wrong time
- derailment because of too high speed.

In order to achieve this protection each moving train is allocated an area of the track network, within which the train can move in accordance with certain rules. Speed limits, signals at stop and stop signs must be strictly observed. The area allocation means that no other trains may move in the area and that points in the area may not be switched as long as the area allocation remains. However, area allocations for shunting do not block point operation.

The track network is divided into geographical areas of different sizes. A moving train can be allocated one or several such areas, depending on such factors as the permitted speed of the train. When the entrance signal to a train route shows "clear", the train route is locked. All points and other devices that belong to the train route are locked in the correct positions, all protective signals show stop and the route is guaranteed free from obstacles, there are no other trains or vehicles in the area, fig. 3.

Interlocking equipment

The conditions that apply for different train routes and train movements can be compiled in an interlocking table for each track area. Conventional signal boxes use safety relays to ensure that all conditions in the interlocking table are

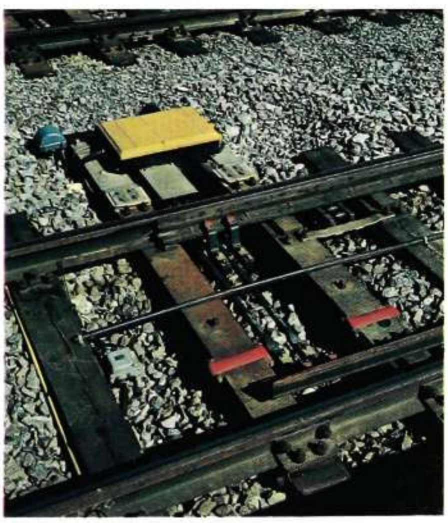


Fig. 4
Point machine for operating points

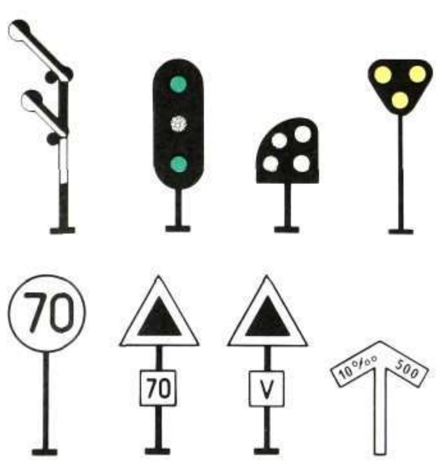


Fig. 5
Some types of signals and signs that are placed along a track

Fig. 6
The train driver must keep a lot of information in his mind in order to be able to drive the train in the best possible way

Fig. 7
Automatic block signals, controlled by track circuits, are used between stations to inform the train driver of the position of the train in front of him

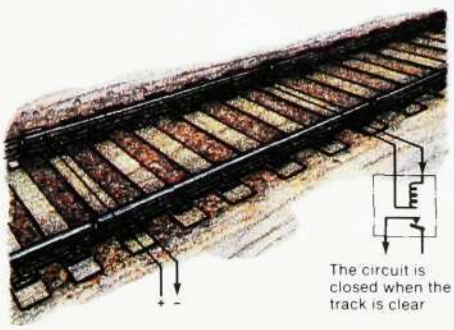


Fig. 8
A track circuit comprises a battery, an insulated part of the track and a relay. The relay is normally operated but releases when a vehicle occupies the track circuit

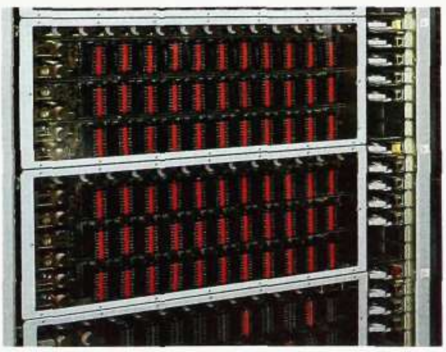
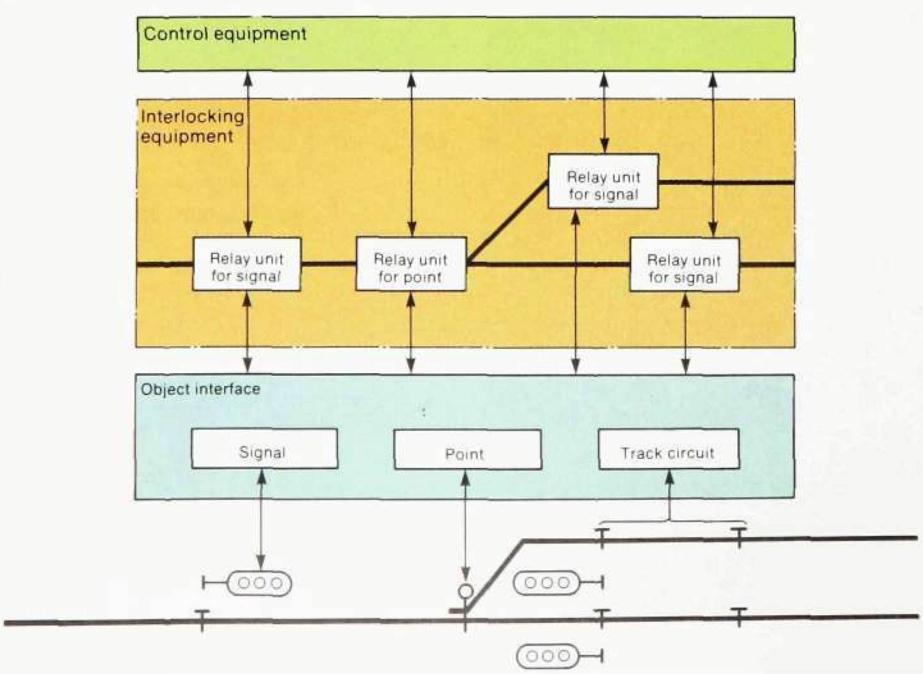


Fig. 9
A "geographical" relay unit for a main signal

Fig. 10
The safety equipment at a station, arranged in accordance with the "geographical" method



met. The relay contacts are connected together to form current paths that correspond to the different conditions.

Another way of stating the conditions is by means of the "geographical" method. The conditions are related to different objects in the track area, points, signals, derailers etc. For each object the conditions are set for each possible state and each possible change of state. The relays that are needed for the interlocking of an object are brought together to a relay unit. One type of relay unit is used for points, another for signals etc., fig. 9. The relay sets, which are also called logic blocks, are connected to adjacent ones by means of multi-wire cables in a pattern that corresponds directly to the track system, fig. 10. The interface between the relay units is standardized.

The same geographical method of stating the interlocking conditions is used in LM Ericsson's computer-controlled interlocking system. In this case the conditions are stated in the computer program instead of in current paths via the relay contacts.

Track circuits

Already at an early stage it was found necessary to be able to ensure, automatically and absolutely reliably, that a track section was free from trains. The oldest and still most frequently used type of equipment is the track circuit. Its design is shown in fig. 8 in its simplest form. A track section is insulated from the adjoining parts of the track. The rails function as insulated conductors. The track circuit is fed with current from a battery at one end. The current through the circuit keeps a relay at the other end operated. The relay releases when a train short-circuits the track.

There are a number of types of track circuits, partly because there are different electrical traction systems for trains. For example, alternating current must be used for the track circuits when the trains are driven with direct current. In some cases the track circuit current is pulsed in order to obtain more reliable function or to combine the track circuit function with inductive transmission of information from the track to the locomotive by means of different pulse frequencies. Two prerequisites for such transmission of information are that the locomotive must be equipped with some form of antenna in front of the first pair of wheels, for receiving the pulses, and also that locomotives enter the track circuit from the relay end.

Track circuits are used to
- check that train routes are free from obstacles
- block any switching of points
- automatically release traversed train routes
- control level crossing protection
- detect the approach of trains
- indicate the position of trains.

Blocking equipment

The section above on interlocking equipment dealt with interlocking in stations. Similar interlocking must of course also be possible between stations. In its simplest form the latter type of interlocking is carried out by means of telephone calls and written routines. Agreements concerning states for train movements between two stations are noted on a form in each station. Sometimes the form routine is supplemented by a technical device that controls the exit signal to the line. With such manual blocking systems there is no need to equip the track sections between the

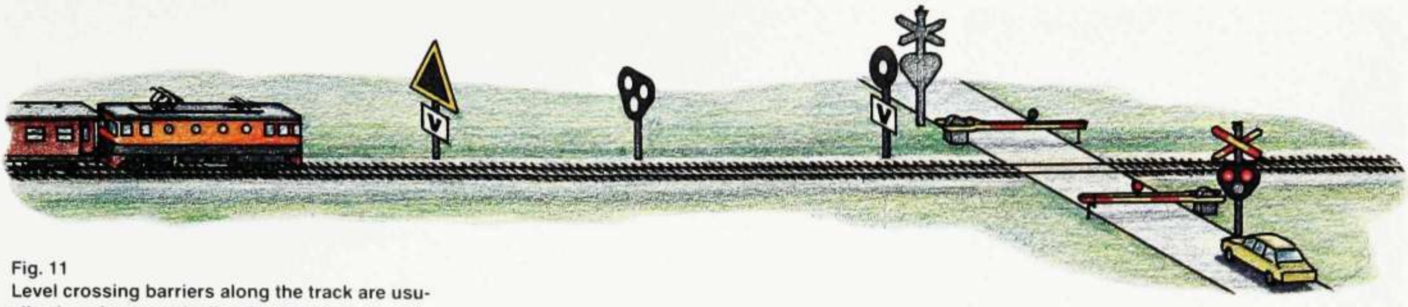


Fig. 11
Level crossing barriers along the track are usually closed automatically when the train approaches the crossing. The distance from the crossing to the point where the barriers start closing is dependent on the speed limit for the track

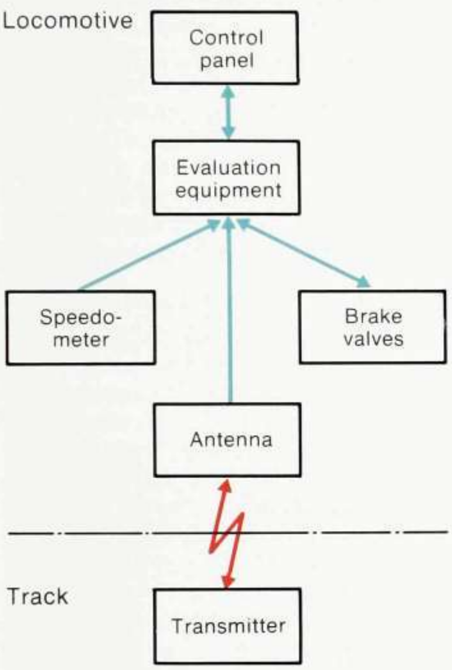


Fig. 12
The parts in an automatic train control system, ATC

Fig. 13
The ATC system supervises that the train does not exceed the speed limits, which are depending on the train itself, the condition of the track and the traffic situation

Automatic blocking systems require track circuits along the whole route between stations. With long distances between stations it is possible to have several track circuit sections and signals, and more than one train can then be moving simultaneously along the track between two stations, fig. 7. When the whole route is free, the block can be turned for traffic in the opposite direction.

Automatic train control

Systems for automatic train control, ATC, supervise the speed of the train and brake the train automatically if the speed limit is exceeded. The transmission of information between the track and the locomotive can be continuous or intermittent, i.e. at intervals along the track. The older systems that are still used in many underground railways have continuous transmission of information, but the number of different messages is limited to three or four speed limits, of which one corresponds to stop. Older intermittent systems usually only transmit stop messages if the train passes a stop signal. In certain cases such systems are supplemented by a function that gives advanced stop warning.

The requirement for safety and at the same time efficient utilization of the track network have led to the track being equipped with a large number of signs and signals, which in good time inform the train driver of the characteristics of the track and the traffic situation. With the aid of this information the train driver is expected to optimize the speed of the train, figs. 5 and 6.

More recently ATC systems with a large transmission capacity have been constructed. Systems for both continuous and intermittent transmission are available. LM Ericsson have developed a system with intermittent transmission, fig. 12. A large amount of track data, such as signal messages, track slopes, curve radii and speed limits are collected, transmitted and processed together with train data, braking ability etc. The processed result is presented to the train driver on a panel, fig. 13. The equipment in the locomotive continuously supervises that the train driver observes the set restrictions, and the train is automatically braked if the speed should exceed the limit at any time.

Level crossing protection

Level crossing protection can consist of
- visual and acoustic signals
- barriers.

The equipment can be operated manually or automatically. Manual operation, particularly of barriers, occurs in densely populated areas. However, protection equipment is usually made fully automatic, fig. 11.

When designing level crossing protection equipment it is assumed that road vehicles should give way to trains. The equipment is usually independent of other signals and interlockings on the track. However, at a station there may be interdependence between the signalling equipment at the station and level crossing protection equipment.

The signal towards the train in independent level crossing protection equipment is usually placed so that the train driver does not have time to stop a train which is running at full speed if he finds that the signal indicates that the protection equipment is not working. It is therefore essential that the signals and barriers for the road traffic are very reliable.

Fig. 14
In stations with local interlocking control the signals may be set with keys in the track diagram

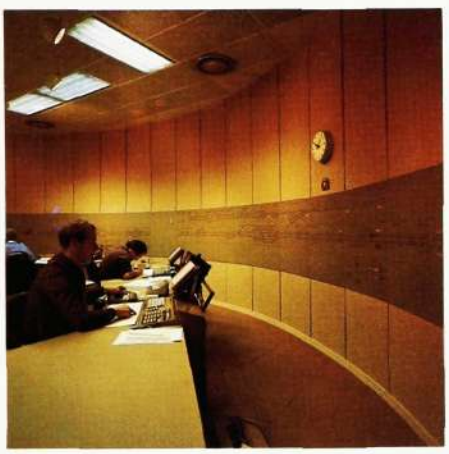


Fig. 15
The CTC centre in Stockholm, Sweden, controls 60 stations and about 400 km of tracks

In Sweden an advanced warning signal to the train at level crossings has been introduced in certain places. Complete signalling towards the railway with absolute stop obligation for the trains would mean unacceptable waiting times for the road traffic.

The increasingly large differences in the speed of different types of trains justify the introduction of a control system for level crossing protection that takes the train speed into account. Such systems are already in use in some places. On sections with automatic train control it is possible to include data concerning the level crossing protection in the information that is automatically transmitted to the locomotives.

Control and supervision systems

Basically the handling of railway traffic is carried out in accordance with a predetermined timetable. Traffic controllers can cancel trains, put on extra trains, change train meeting places, change the order of trains and carry out any measures that are made necessary by, for example, engineering work on the tracks within their district.

Station masters at manned stations, fig. 14, and dispatchers at remote control centres, fig. 15, control and supervise the train traffic via control panels. Certain of the tasks of traffic controllers, for example changing train meeting places and the order of trains, can be delegated to remote train dispatchers. The method of establishing a centre for the control and supervision of the traffic in a large geographical area with many stations is called centralized traffic control, CTC.

Centres that handle a large volume of traffic can be equipped with various aids, for example for the recording of train numbers and their display on track diagrams, for automatic route setting and for traffic recording. Traffic recording simplifies statistical follow-up of the train traffic.

LM Ericsson have developed an advanced control and supervision system for areas with high traffic. The system is computer-controlled, uses colour display screens for all indicating and constitutes a means for efficient and rational traffic handling, fig. 16.

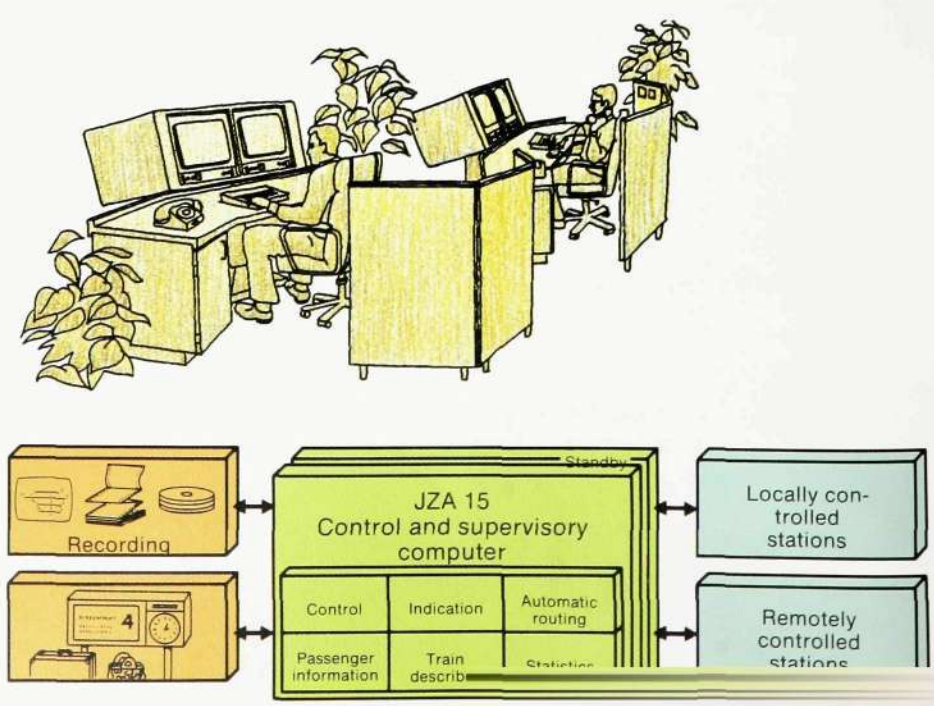


Fig. 16
A computer-controlled control and supervisory system with colour display screens for large stations and for remote control of a large geographical area with many stations

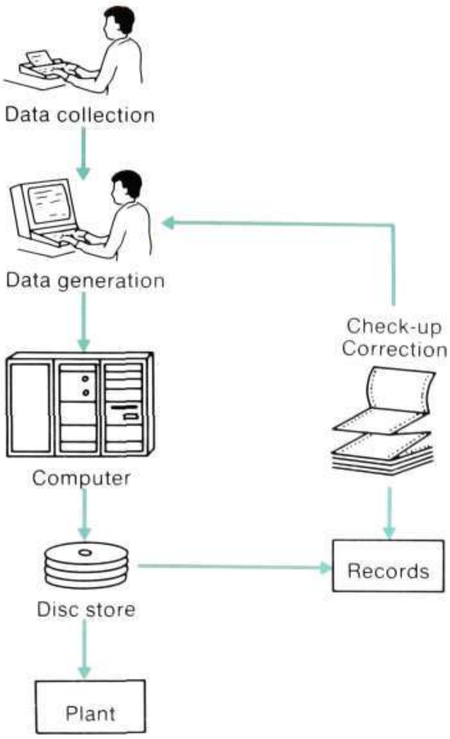
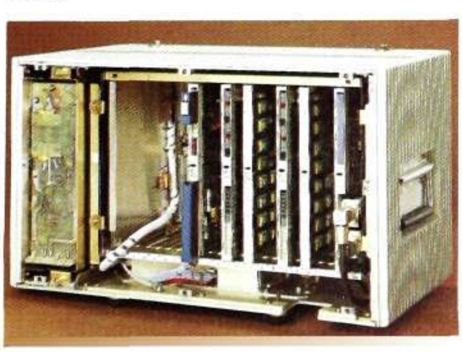


Fig. 17
A computer aid is available that greatly simplifies the work of preparing the data and documentation that is individual to each installation

Fig. 18
Plug-in safety relays are still predominant in interlocking systems not using "geographical" system as in fig. 9

Fig. 19
The evaluation equipment for ATC is based on stored program controlled micro computer technology



Product stipulations

Stringent safety requirements are made on many items in the product range in fault situations. A simple failure must not cause a dangerous situation. Moreover a failure must be detected and cleared fast enough to exclude the possibility that another failure appears which, combined with the first, endangers the safety. This affects the design and manufacture. Great precision is required in the production testing. In addition the equipment will be exposed to great stresses. The heavy railway traffic causes large mechanical vibrations. The traction current is returned partly through earth, and this gives rise to strong electrical disturbances. For example, the disturbances can be very troublesome when the traction current is taken from 16 kV single-phase $16\frac{2}{3}$ Hz a.c. voltage and the locomotive has thyristor control. Furthermore certain equipment must be able to withstand both arctic and tropical climatic conditions.

There are standards for the construction of railway signalling equipment, but the standards are not the same in all countries. However, most conventional equipment with essential safety functions is constructed in accordance with specifications issued by the Association of American Railroads, AAR, British Standards, BS, or the Office de Recherches et d'Essais, ORE, which is a working agency within the Union Internationale des Chemins de Fer, UIC. The construction standards are designed for contemporary technology and usually have to be altered when a changeover is made to new technology. The degree of safety that is obtained with robust relays and large insulation gaps between the circuit elements corresponds to what is obtained with high information and system redundancy in computer-controlled systems.

The traffic regulations also have many national characteristics. The position and meaning of visual signals are different in different countries, as are the conditions for the protection of train movements. Different experience and different assessments have led to different rules and regulations.

These rules and regulations are not greatly affected by a changeover to a new technology. However, in order to be able to apply them in connection with computer-control, it is necessary to give them a more stringent mathematical expression, so the rules and regulations must be rewritten in the form of a process algorithm. This has been done in the develoment work on LM Ericsson's new computer-controlled interlocking system.

Development trends

Intensive development work is being carried out to utilize the facilities provided by new technology for better use of track and rolling stock, partly through higher speed and denser traffic. The railway administrations are also striving towards increased rationalization of the activities and increasing traffic safety. This requires

- efficient control of train traffic
- increased use of ATC systems
- more suitable level crossing protection, for example through the introduction of a control depending on the trains' speed
- equipment that is reliable and easy to service, and which needs only simple planning (fig. 17), short installation time with low manpower requirement and is easy to extend
- interworking of different administrative sections, for example through joint use of the transmission equipment for telecommunication, power and signalling purposes.

The technology based on relays, fig. 18, which is now predominant in equipment with safety requirements, will in the long run be replaced by stored program controlled computer technology where the microcomputer in particular is likely to become very important, fig. 19. One reason for this development is that the cost of relay-based technology increases successively relative the cost of electronics.

Data transmission is increasingly being used for the new systems. Fibre optics could with advantage be used for this purpose in order to overcome the difficult electrical interference problems. Data communication via radio from control centres to the locomotives may also come to be more widely used.