Longest C.T.C. Line in Europe

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C.T.C. has become an acknowledged and increasingly employed means of modernization of operations on the Swedish State Railways, which in January 1961 opened the first section of what will be the longest C.T.C. line in Europe, between Ljusdal and Mellansel on the main route between Stockholm and Boden. Mr. S. Lundgren, the Chief Signal Engineer of The Swedish State Railways, gives an account of the technical principles which the Swedish, Norwegian, Danish and Finnish Railways have considered necessary for operation of C.T.C. plants and describes, firstly, two important C.T.C. plants installed prior to the Ljusdal–Mellansel system, followed by a fuller description of the latter installation. He also gives some account of the future plans of the Swedish Railways. He does not deal with the technical aspects of the C.T.C. system, since these have been described in earlier articles in Ericsson Review (No. 4, 1954, No. 2, 1958, and No. 3, 1960).

The first C.T.C. system in Sweden was installed in 1938 on the Stockholm–Staltsjöbaden line. Plans for additional C.T.C. installations were interrupted by the war. After the war a committee of the Swedish, Norwegian, Danish and Finnish Railway Associations was appointed to study problems of centralized

Fig. 1 X 7823
C.T.C. office, Ånge
Note the two traingraphs built into the control desk

traffic control and in 1953 presented proposals for technical principles for C.T.C. systems. The main points were as follows:

> The C.T.C. control equipment shall control the local signalling plants consisting of relay interlockings and automatic blocks of the railways' normal standard. The equipment shall be fully reliable but need not fulfil the rigorous safety requirements placed on the signalling plants. It shall be constructed of modern telecommunications material of good quality. Rotary switches should not be used.
>
> Information between C.T.C. office and field locations shall be transmitted on a single pair of wires by means of d.c. pulses of different polarity.
>
> The speed of transmission shall be sufficiently high to limit the quantity of transmitted information to a level such that delays in transmission are negligible.

Electronic components were not considered sufficiently reliable to justify their recommendation. This is the reason for recommending d.c. pulsing, which, in itself, has certain limitations when it comes to transmission over long distances.

The committee completed its work in 1957 by summarizing the experiences gained from C.T.C. installations in Sweden, Norway, Denmark and Finland. There had hardly been time for any new features to appear as regards the technical design of C.T.C. equipment. But there was ample evidence that the introduction of C.T.C. should be combined with modernization measures within other branches of railway operation.

Trial Installation Ånge—Bräcke, 31 kilometres

The traffic situation on the Ånge–Bräcke section of the main Stockholm–Boden line had become so desperate as to necessitate the immediate building, at a cost of 15 million kronor, of an additional track, which, to be sure, had long been foreseen. The alternative was to provide new sidings and introduce C.T.C. This would involve only a tenth of the cost of an additional track and could also be done fairly quickly. The economic gain afforded by C.T.C. was expected to be very considerable, since the four stations on the line could be left fully unattended, there being no local traffic duties. Consequently it would also be unnecessary to build residential quarters at the new sidings. It was considered that C.T.C. would provide the visual survey required to permit an efficient flow of traffic on the heavily loaded single track. The section was likewise judged to be sufficiently large for a trial installation, which would provide the necessary experience for subsequent larger installations. It was therefore decided to introduce C.T.C. on the Ånge–Bräcke line, in combination with new sidings, as soon as possible. A plant designed to the specifications of the Swedish, Norwegian, Danish and Finnish Railway Associations was ordered from L M Ericsson and opened on June 10, 1955.

The Ånge-Bräcke installation had certain characteristic features which have been retained in later Swedish Railways installations. It had keyboard operation, for example, and its system of control numbers has been employed elsewhere practically unchanged. The number of indications normally presented on the track diagram had been cut to a minimum. This was achieved by using a Total Indication Panel on which indications which are of interest only on special occasions are presented for one station at a time. These indications are sent from a field location only in response to a special control and normally, therefore, do not load the transmission system. This arrangement has also been retained virtually unchanged in later installations.

In L M Ericsson's C.T.C. control equipment, the selection of station and control was effected with 4×6 pulses, which gave a number capacity of 36 stations with 36 controls per station. The indication system was designed for scanning of 49 indications per station, in groups of seven. To comply with the committee's recommendations, the station and control selection was modified to a pulse code system without redundancy. Using five pulses for station selection and six for control selection, this resulted in a number capacity of $2^5 = 32$ stations with $2^6 = 64$ controls per station. In the indication system, corresponding arrangements were introduced for station identification, while the earlier scanning system was retained for the actual indications. The capacity of the installation was thus raised to 64 controls and 49 indications per station. Each control, however, requires at least one indication transmission; and furthermore certain information must be transmitted without relation to control transmission, for example the indications which show the locations of trains. The proportion between controls and indications per station was therefore unsatisfactory and in later plants the indication system has been modified to provide $2 \times 49 = 98$ indications per station.

The design of the local signalling plants involved no great difficulty. The four siding stations had only two tracks, and no provision for shunting, except to remove faulty cars, appeared to be necessary. To facilitate the C.T.C. operator's work and increase the rapidity of movement of meeting trains, the principle of storage of routing controls was introduced to an extent which allowed all controls required for a meeting at a station to be sent in advance. The storage function was placed in the local interlocking plant, which had the advantage that the control section of the C.T.C. system need not provide for individual variations. This arrangement proved effective and has been retained in later installations.

Precise instructions for the despatch of trains with full safety have long existed in the Swedish Railways Safety Regulations. The introduction of C.T.C. necessitated extensive additions to these regulations. As already mentioned, the basic idea in the engineering of the C.T.C. system was that the safety functions should lie in the local interlockings, which should incorporate all safety functions which previously had rested on the stationmasters. The trains would therefore have to be protected by automatic means, which meant that all tracks must have track circuits. This actually resulted in a higher degree of safety than is possible under a verbal system of train control. The double control of meets, normally resting on the train crews, could thus be eliminated, including the laborious system of written notifications to train crews concerning changes of meeting stations. With a complete control of tracks by means of track circuits, there is in principle no need for a fixed timetable, since C.T.C. gives the operator the necessary survey of train movements. But, for the safety of trackmen, the present rule is that trains shall not run more than 5 minutes ahead of scheduled time. It is to be hoped that better methods will be found for informing trackmen of changes in train times so as to allow the C.T.C. operator greater freedom in directing train movements on an optimum basis.

It is normally part of the duties of a stationmaster to make sure that a train entering a station has stopped before he allows an opposing train to run in. There are, unfortunately, occasional instances when the train cannot be brought to a stop until a few yards beyond the exit signal, which means that the locomotive may obstruct the meeting train. After thorough discussion it was decided that the home signal for a meeting train should not be cleared until the crew of

Fig. 2 X 2605

In northern Sweden the points are electrically heated to ensure their functioning in cold weather

the first arrival has confirmed that the train has stopped by pressing a button at the exit signal. This was considered to be a cheaper and sufficiently reliable alternative to the provision of protective points at the ends of the tracks. Since, so far as is known, no other railway has adopted similar arrangements, the precaution is presumably exaggerated; but once these buttons had been introduced, it proved difficult to do without them.

With the chosen form of control system and track diagram, the equipment was so small that it could be accommodated in the existing stationmaster's office at Ånge. The relay racks were placed in the basement below.

The experience of this trial installation has been generally satisfactory. The primary aim of increasing the capacity of the line without adding an extra track or manning the siding stations has been accomplished. The traffic side has admittedly not wished entirely to write off the plans for double tracks, but the Ånge–Bräcke line has been moved to the bottom of the list of urgent reconstruction jobs.

As might be expected in a trial installation, various disturbances were encountered during the first year. One of the lessons learnt was that the maintenance requirements for the local signalling plant must be placed very much higher than had been customary earlier, when there were station staff available to deal with a fault. For the same reason standby power had to be provided. Electric heating of points (fig. 2) had been foreseen from the outset.

High requirements had to be placed on the telephone system which links the line signals with the C.T.C. office. The telephones are a very important feature when a disturbance occurs in the C.T.C. system and should preferably operate independently of it.

The traffic regulations provide for the movement of trains without undue delay in the event of isolated signal faults, without need for manning the stations. In principle, stations need be manned only on the occurrence of overall faults of long duration in the C.T.C. system. This has happened only on rare occasions on the Ånge–Bräcke line, two of which were due to damage, during work on the track, of the cable used for C.T.C. transmission.

Kiruna—Björnfjell, 127 kilometres

Simultaneously with the C.T.C. trials on the Ånge–Bräcke line, the signal installations on the northern section of the Ore Line[1] were being extended, primarily in order to equip it with automatic blocks and relay interlockings. The decision to introduce block signalling on this line was initially due entirely to safety considerations since, by Swedish Railways standards, it is an unusually heavily trafficked single-track line. The division of the station-to-station sections into block sections at the same time yielded a slightly higher carrying capacity. This line as well has little local traffic, and there seemed to be good propects of saving manpower at siding stations through the introduction of C.T.C. In view of the satisfactory experience also from the Ånge–Bräcke line, is was decided to install C.T.C. control equipment for the control of the line Kiruna–Björnfjell (Björnfjell lies on the Norwegian side of the frontier). The equipment was delivered in the spring of 1958 and brought into service on June 1 of the same year.

[1] The Ore Line is the popular name for the line in northernmost Sweden from Luleå to Riksgränsen on the Norwegian frontier, used mostly for the carriage of iron ore.

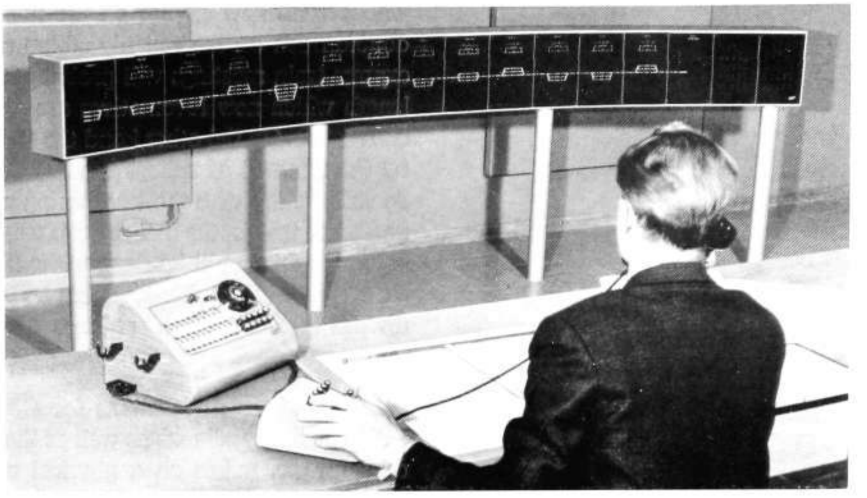

Fig. 3 X 8227

Original C.T.C. office in Kiruna for control of line Kiruna (Sweden)—Björnfjell (Norway)

The system has since been extended southwards to Gällivare and controls now altogether 22 stations over a distance of 229 km

The C.T.C. line is about 130 km in length and has 13 siding stations, of which 12 are at present[1] under remote control. The C.T.C. office is at Kiruna, being housed in a new building which also contains a modern interlocking plant for the Kiruna Ore Yard, the departure station for the ore trains. The system has functioned so reliably that, at stations without local traffic duties, all staff have been withdrawn with the exception of, generally, one man at every third station. The disturbances which occur are chiefly in the local signalling plants, particularly in the parts which are connected to the track. The close headway and the severe climate during a large part of the year have made it very difficult to keep the track in the best condition. Two total breakdowns have occurred in the C.T.C. system, both due to damage of the telephone cable during track maintenance.

New tonnagemile records for the line have been established on several occasions during the past years, the latest being in April 1961. They are attributable largely to the provision of longer sidings and better rolling stock, but the C.T.C. system has undoubtedly been an important factor. So long as no trouble occurs and the nominal timetable can be followed, C.T.C. does not in itself increase the capacity. But dislocations, due for example to locomotive damage, are inevitable. When the line capacity is fully utilized, a primary disturbance may result in a total stoppage of traffic. In practice, therefore, gaps must be allowed in the timetable to give time to deal with disturbances. C.T.C. assists in limiting the secondary disturbances and, in practice therefore, does increase the capacity by reducing the need for gaps in the timetable.

Fig. 4 X 2595 X 9151

The map shows the Swedish Railways C.T.C. plants already installed or scheduled for installation, all of which have been or are to be delivered by L M Ericsson

■ C.T.C. office

▮▮▮▮▮ C.T.C. line

Ljusdal—Mellansel, 358 kilometres

The Ljusdal–Mellansel section (fig. 4) is a critical part, from the point of view of train movements, of the long single-track line from Krylbo to Boden, the main north Swedish line. In the middle of the section lies Ange, a main junction for goods traffic. It has hitherto had 35 stations at fairly irregular intervals of between 7 and 14 km. The maximum speed is still 90 km/hour, which means that the line is heavily burdened despite the fairly moderate number of trains—about 50 trains a day south and 40 north of Ange. Some stations are in out-of-the-way places and, moreover, have poor staff dwellings. It is difficult to staff the stations and they are often left unattended during a large part of the 24 hours, to the detriment of operation, especially when dislocations occur. Since the main line to Boden is one of the lines on which there is the greatest prospect of an increase in traffic, it has long been plain that something must be done to step up its capacity. Following the successes on the Ånge–Bräcke section, it was decided to adopt a combination of C.T.C.

[1] Since the time of writing, the system has been extended southwards to Gällivare and now comprises 22 stations over a distance of 229 km.

with certain new sidings on the longest stretches between stations, and with double track on the roughly 60-km stretch south of Ånge, where most of the express train meetings will probably take place. To permit goods trains of the length which new locomotives are able to pull, all sidings were prolonged to 650 metres. On the other hand the track system at many stations was simplified by the removal of sidings used for traffic which has now been discontinued. In conjunction with the lengthening of sidings, and when justified by the local passenger traffic, the main routes were moved away from the station buildings, wherever this could be done without undue cost, in order to reduce the risks of personal injury from passing trains. Station intervals of above 8 km were divided into two block sections.

In the choice of locations for C.T.C. offices, it was necessary to consider the technical conditions as well as the traffic demands. Since the C.T.C. system employs d.c. pulses on a physical circuit, its range is limited unless special equipment is added. The limit lies at 5,000 ohms' resistance and a capacitance of 8 μF. Wire pairs with 1.3-mm conductors were available, and an office without special auxiliary equipment could control a distance of about 200 km in each direction. Since the office should obviously be located in Ånge on traffic grounds, it was logical that the Ånge office should control the Ljusdal–Långsele section of line. Långsele is an important junction and, moreover, lies on the boundary between different traffic sections. It was therefore natural to place a second C.T.C. office in Mellansel with the idea of subsequently controlling from it a corresponding length of line northwards. Later, however, it proved better to make the C.T.C. areas larger than had been initially planned, and it was therefore decided to place the office for the Långsele–Mellansel section at Vännäs for subsequent control of the entire line from Långsele to Jörn.

As already mentioned, the length of line which can be *directly* controlled from a C.T.C. office—that is a C.T.C. section—is limited. It is actually limited by three factors, each of which under different circumstances may be the decisive one. With large distances between stations and sparse traffic, the limit is set by the resistance. If there are many stations but sparse traffic, the critical factor may be the station number capacity, which is limited to 32 stations; but this is very seldom the case. And thirdly, with dense traffic, the congestion on the line is the decisive factor. The Kiruna–Björnfjell line has been made into a single section without any troublesome congestion occurring, and it should therefore have been possible to form single sections of the Ljusdal–Ånge and Ånge–Långsele stretches. But, in the latter case, since the traffic was heavier and, moreover, faster and more irregular, it was decided to divide each stretch into two sections. In the event of a total breakdown due to failure of a transmission equipment, the disturbance will then be more limited. Moreover, since the transmission equipments in the C.T.C. office can to some extent act as standby for one another, the main rise of cost will be in the physical circuit from the C.T.C. office to the beginning of the more remote sections.

If it is found desirable to have large C.T.C. areas, a limit will soon be reached at which the resistance condition cannot be fulfilled for the most remote sections, even if phantom or superphantom circuits are used up to the section boundary. For this reason conversion equipment has been designed so as to permit the use of two two-way telegraph circuits for that link.

Work on the local interlockings for the C.T.C. plant was started in 1957. The pace of this work had to be adjusted to the very considerable work on track reconstruction, the extent of which may be appreciated from the fact that, on the Ljusdal–Långsele section, track reconstruction has cost 52 million kronor, while the signalling plants including the C.T.C. system cost only

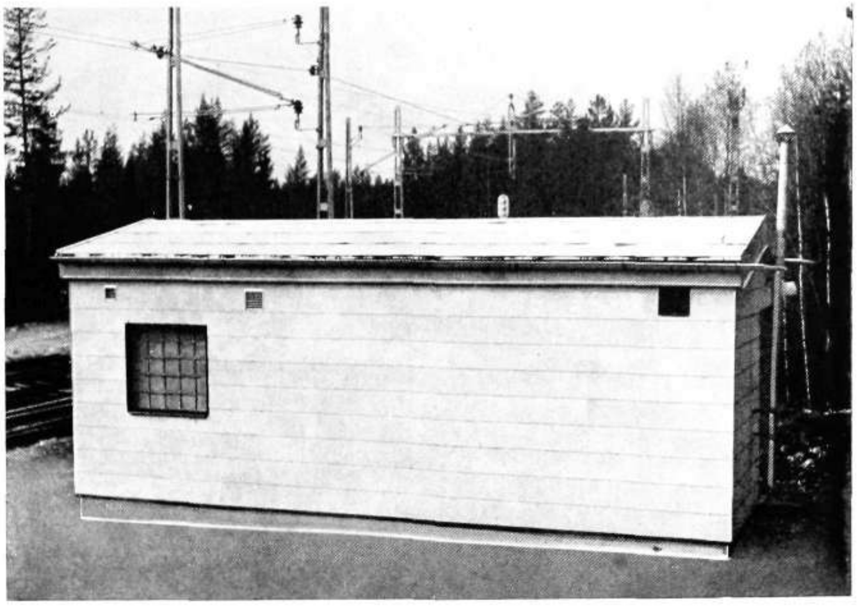

Fig. 5 X 8291

Relay buildings of lightweight concrete have replaced the old station buildings

11 million. The work has therefore proceeded fairly slowly and it was not until January 30, 1961, that the Alby–Bispgården section, 135 km, could be completed. The Bispgården–Mellansel section is expected to be in service by the year end 1961.

Various station buildings on the line are in poor condition and need extensive repairs. They are also too large for their new functions. They are generally timber structures. In many cases, therefore, it was questionable whether they should be retained, since the stations might be unattended. The local relay equipments and local control panels have in most cases, therefore, been placed in small lightweight concrete buildings of standard design (fig. 5). This has had the advantage that locomotive crews and other persons who may have to employ the local control panel (fig. 6) can find it immediately. The control panels are also clearly marked with explanatory text to facilitate their use by unaccustomed persons.

After some reconstruction of the Ånge station building, an acceptable, even if not ideal, control room was formed (fig. 1).

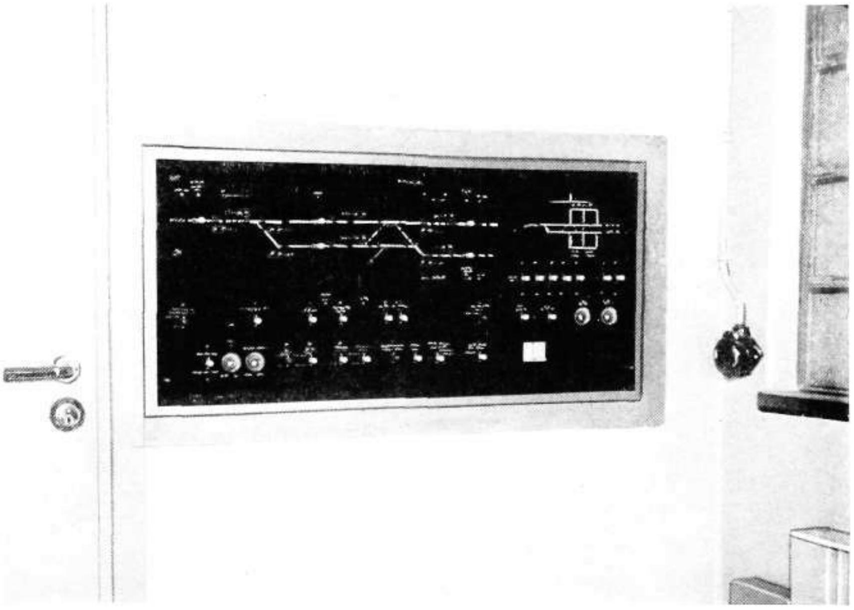

Fig. 6 X 8292

Each station relay building is divided into two compartments. On the dividing wall is a control and indication panel from which the station's signal system can be locally operated when necessary. The other room contains the interlocking and remote control relays.

At Vännäs a building is being constructed which will contain accommodation particularly designed as a C.T.C. office to control the Långsele–Jörn section, with spare accommodation for later control of secondary lines.

The track diagram and the keyboard control system have been described in Ericsson Review No. 2, 1958. The operator's work is facilitated by the provision of traingraphs, two in the Ange office and provisionally one at Vännäs. The traingraphs are placed on separate control desks (fig. 1). It is calculated that, when fully extended, the Ange office will have three operators during heavy traffic periods, two of whom will have keyboards, controlling one half of the installation each, while the third will act as assistant, keeping notes and making telephone calls. The office is designed to permit operation from a single position during light traffic periods. Experience has shown that most of the operators' time is taken up, not on directing train movements, but on fitting in track maintenance between train movements and arranging for transport of the track gangs.

Contact between locomotive drivers and C.T.C. office is established on a selective calling telephone system designed for secrecy of conversation and compulsory check-back to preclude any possibility of mistakes in the issue of orders. There is a separate, non-secret selective calling telephone system for contact with track maintenance gangs.

The Swedish Railways expect that the planned reequipment of the line will give it an adequate capacity during the foreseeable future. C.T.C. will allow the re-equipped line to operate economically, since the traffic staff will be cut by about 70 men.

Future Plans

The manpower saving attendant on C.T.C. is so great on lines of the average Swedish Railways type that it covers the costs not only of the C.T.C. equipment itself, but also of a large part of the local signalling plant. Since the latter will in any case have to be modernized sooner or later and brought up to a standard consistent with the day's demands for traffic safety, and since C.T.C. leads to improved railway operation, C.T.C. should prove a profitable investment on practically all lines which will be retained in operation in future. Further thought must still be given to the question of which are the most important projects. In order to be able to make long-term plans for the extension of station yards and the provision of signal towers, the Swedish Railways are at present preparing a plan of the areas which would be suited for C.T.C. if C.T.C. were to be introduced within the major part of the railway network which is expected to be still operating around 1980. Thereafter it is planned that a continuous flow of C.T.C. installations shall be built at a rate consistent with the Railways' financial and personnel resources.

The Kiruna–Gällivare section is to be commissioned in September 1961, and work is in progress on the Gällivare–Boden section. Next on the list is the West Coast line.

If so extensive a programme is to be successfully accomplished, particular attention must be paid to the reliability of the technical arrangements. Arrangements for limiting the consequences of technical faults will presumably have to be introduced on a hitherto unprecedented scale. Consideration must be given, for example, to the need for connecting either end of a section to the C.T.C. office over any length of circuit so as to permit the use of alternative circuits in the event of cable failure. The use of static components in the transmitting equipments should now be feasible, moreover, with a view to increasing their life and reliability with only moderate maintenance.

The large quantity of apparatus will make maintenance an important economic factor. Advances in the component field, however, suggest that future equipments will need less supervision than those of today and that it should be possible to maintain them in good condition with a moderate maintenance force.