EXCERPT
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SOME DETAILS OF THE NEW ELECTRIC SIGNALLING PLANT AT GOTHENBURG CENTRAL STATION: ITS DESIGN, INSTALLATION, AND USE

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Some Details of the new Electric Signalling Plant at Gothenburg Central Station: its Design, Installation, and Use.

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The program for reconstructing the Gothenburg Railway Yards, which was started after long investigations and negotiations in 1927, included the building of a new main passenger station, for the common use of all the standard gauge railways entering Gothenburg except the purely local one to Särö. The new station was to replace the two former passenger stations, Gothenburg B. J. and Gothenburg S. J., of which the former belonged to Bergslagen Railway Co, and the latter to the State Railway. Gothenburg B. J. was the terminus of the Gothenburg—Borås Railway and the State-owned West Coast Line as well as the Bergslagen Line. Two State Railway lines ran into Gothenburg S. J., viz. the Bohus and the Western Main Line. The new passenger station was to be on the site of Gothenburg S. J. and to be built and managed by the State Railway as a union station called Gothenburg Central. The new station was finished in May 1930.

The amalgamation was made principally for the purpose of providing greater facilities for the public, two separate passenger stations being inconvenient for the travelling public and hindering through traffic between the various railway lines. It was also thought that the amalgamation would reduce operating expenses, so that an immediate profit on the capital outlay might be expected.

A modern electric signalling plant was an important part of the great project. The installation, from the very first, of such a plant in the passenger station made it possible, in estimating the track facilities, to allow shorter intervals between necessary shunting and train movements than could have been done if a less modern signalling system were to be used, thereby making it possible to limit the number of platform tracks required from 12 to only 10, with a reserve track for departing trains. Right from the beginning this meant a considerable saving, which might be credited to the account of the signalling system.

Incoming and outgoing lines.

The railways entering the new passenger station are shown in fig. 1. The trains arrive either by Almedal or Olskroken. The West Coast Line from Trälleborg and Hälsingborg via Varberg, and the Borås Line from Alvesta via Borås, come in by Almedal. The Western Main Line from Stockholm via Falköping, the Bergslagen Line from Oslo and Falun via Mellerud, and the Bohus Line from Strömstad via Uddevalla come in by Olskroken.

The connexions between Gothenburg C on the one hand, and Almedal and Olskroken on the other, can be seen from the plan of the Gothenburg Railway Yards in fig. 2, and also from the track diagram of the passenger station shown in fig. 5, in which the names or numbers of tracks, points, and signals are indicated.

Between Gothenburg and Almedal the trains from the West Coast and Borås Lines run on a joint single track, the *Almedal line,* 3.4 km. in length; at 1.2 km. from the outermost points of Gothenburg there is in this line a branch for the goods trains. These do not enter the Central Station, but are taken directly to and from the joint goods yard, which occupies the site of the former Gothenburg B. J. passenger station. The goods trains accordingly do not touch the new passenger station except in so far as the diverging points, and the signals for train movements through these points, are controlled from the passenger station signal-cabin.

Between Olskroken and Gothenburg C, the trains of the Western Main Line and the Bohus Line run on a joint double track, the *Up Line* and the *Down Line,* the length of which between the outermost points is 800 m. Between the same

THE GOTHENBURG RAILWAY YARDS in 1930

Scale: 1:4000

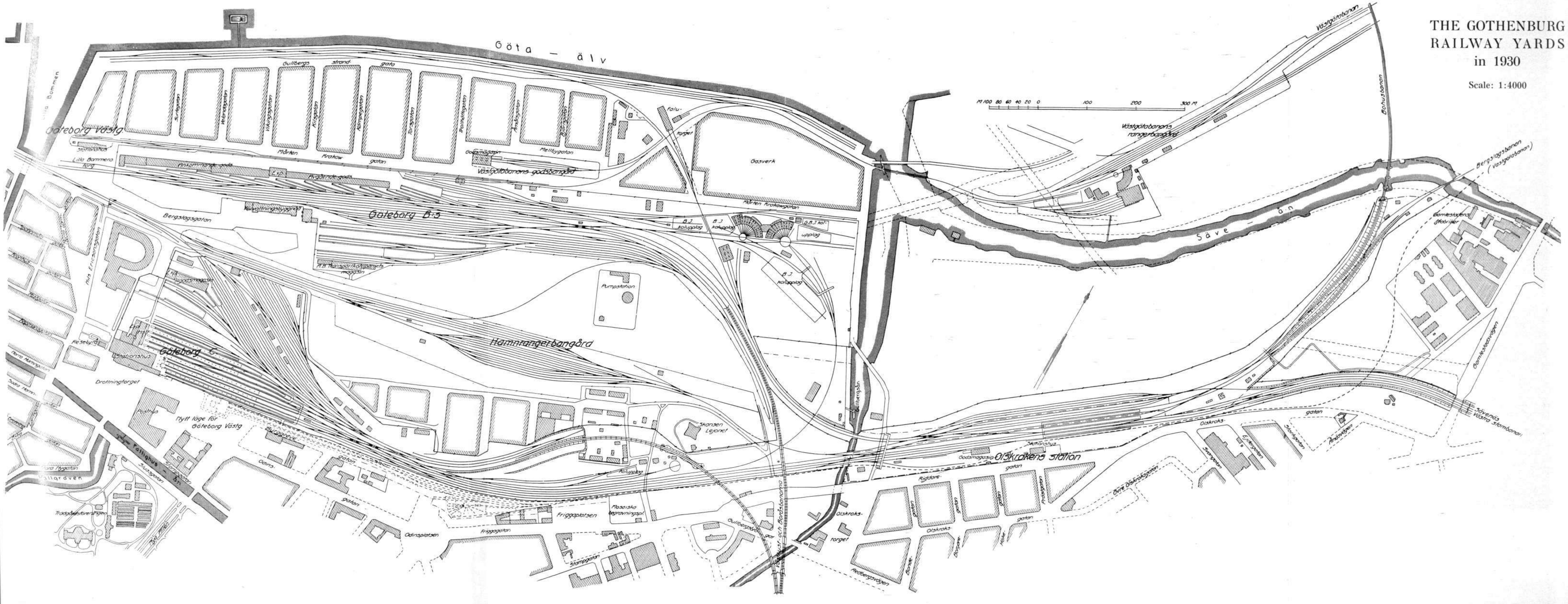


Fig. 2.

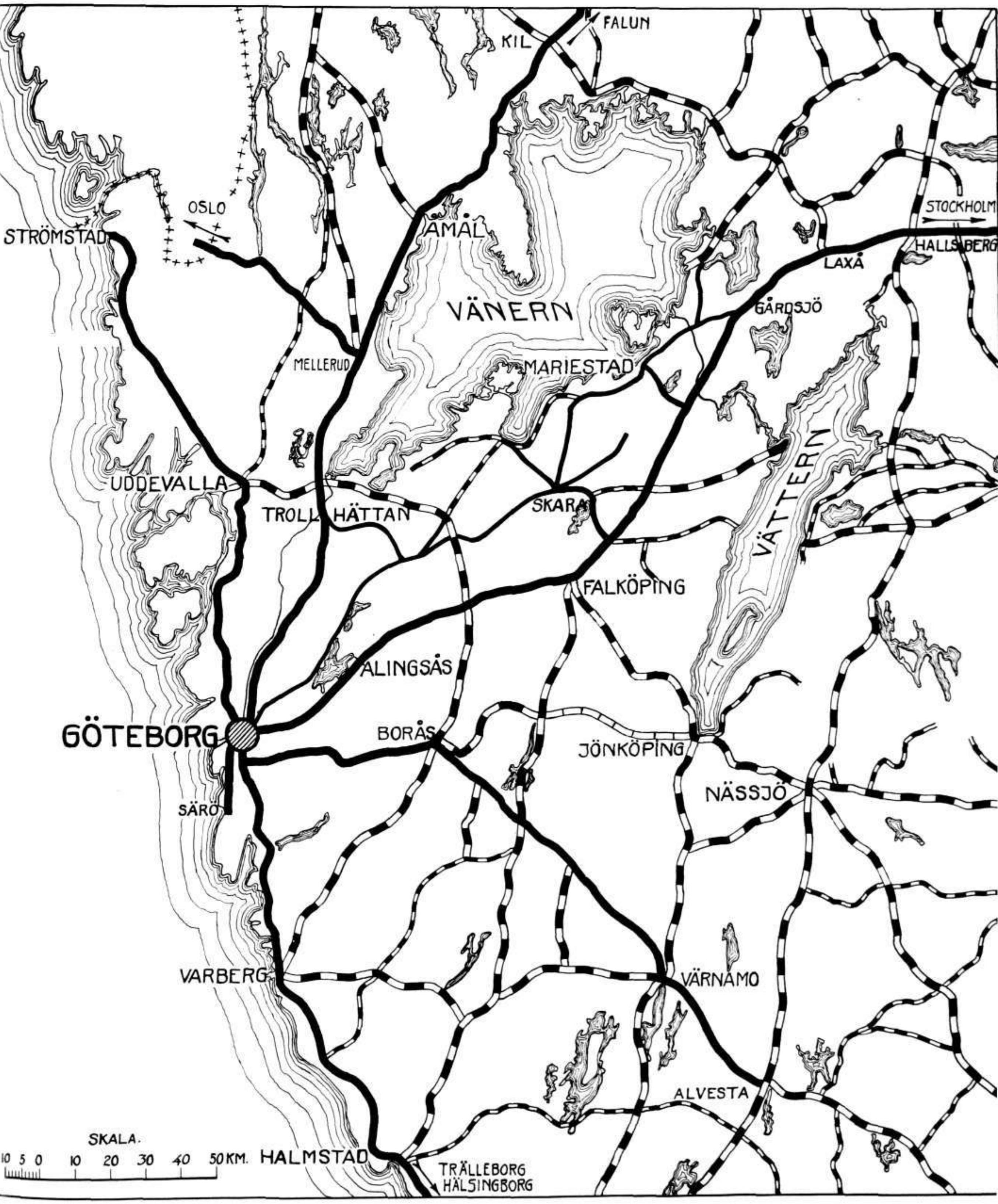


FIG. 1. MAP OF THE RAILWAY LINES RUNNING INTO GOTHENBURG.

stations there is also a separate single track, 800 m. in length, the *B. J. Line* for the trains of the Bergslagen Railway.

Besides these, there are two other tracks, the *North Loop* and the *South Loop*, between Gothenburg and Olskroken, used principally for locomotives on their way to and from the sheds, which are situated beyond Olskroken station. The locomotives of the Bergslagen and the Borås Railways use the North Loop and the State Railway the South Loop. A number of single locomotives are also run on the double track.

The number of scheduled movements on the lines running into the passenger station is shown in the table below.

	Express trains	Ord. trains	Local trains	Engines	Goods trains
Down Line	6	18	26	10	—
Up Line	6	20	27	7	—
South Loop	—	—	—	83	—
B. J. Line..........	10	15	7	—	—
North Loop	—	—	—	61	—
Almedal Line	15	24	29	—	19
	37	77	89	161	19

The total number of scheduled movements to or from the lines using the terminus is therefore 383 in twenty-four hours.

Line Blocking.

All the lines connecting Gothenburg C with the adjacent stations were provided with signals for line blocking. The Olskroken lines were provided at each end with a fixed signal automatically controlled by a track circuit over the whole line. In fig. 5, for example, the signals 5h and 5v apply to the North Loop, 7h and 7v to the B. J. Line, etc. The signals are controlled by signal levers (5,7 etc.), one for each line. If a lever is reversed to the right (h) or left (v), the signal is cleared at the Olskroken or Gothenburg end of the block section respectively, but will not show "proceed" unless the track circuit is free from vehicles. The line blocking works entirely automatically for trains in the same direction, as long as the signal lever is kept in the reversed position.

The signal lever can be restored to the normal position when a train occupies the block section and the signals at both ends are at "stop". If the signal lever is to be restored when there is no vehicle on the track circuit, a special time-switch has to be used, so arranged that the signals for both directions must show "stop" for a certain length of time before another "proceed" can be given. This permits a train which has already received the proceed indication but fails to see or sees too late a subsequent stop indication to enter the block section and shunt the track before "proceed" can be given to a train in the opposite direction. The time switches are operated by springs and can be adjusted for time intervals of up to 2 minutes. There are 6 of these time switches, one for each track.

Both the Up and the Down Lines were provided with signals for both directions, although under normal conditions double track working is arranged, that is, the Down Line is used for trains to Gothenburg and the Up Line for trains from Gothenburg. If one of the lines must be given up on account of work on the permanent way or on the trolley wires, or if there is an exceptional density of traffic in one direction, single track service can be arranged on the other track with complete protection, by means of signals.

While only one block section was required for each of the tracks between Olskroken and Gothenburg C, the Almedal Line, to make shorter intervals between trains possible, had to be divided into two block sections, 1 800 m. and 1 400 m. in length. The difference in length was due to the fact that in the section next to Gothenburg C, the northern section, speed has to be reduced considerably when passing a viaduct running in a sharp curve over the Olskroken lines.

The northern block section also includes the track between the outlying points 2 and the entrance signal to the goods yard. When a signal is cleared to enter the northern block section, the tracks must be free from vehicles both to the goods yard and to the passenger station.

The signals for the northern block section are arranged on the same principles as those for the lines between Gothenburg C and Olskroken. There are entry signals to the block section both from the direction of Almedal (1h) and from the goods yard (1va) and Gothenburg C (1vb). The signals are also intended to safeguard movements of trains through the outlying points 2, which are operated from the Gothenburg C signal cabin.

The signals B1 and A2 control the entrance to the block section nearest to Almedal, i. e. the *southern* block section. These signals are all-automatic and no levers for them are provided in the frame in the Gothenburg C signal cabin. In normal position "proceed" is shown. When the lever 1v at Gothenburg C is reversed to prepare for a train movement from Gothenburg C or the goods station towards Almedal, A2 will show "stop", where it is held by the track circuits until the train has arrived at Almedal. When a train leaves Almedal for Gothenburg C the conditions are different. The signal A2 is then independent of the track circuit of the northern block section and may show "proceed" for a following train from Almedal as soon as the first train has passed out of the southern section.

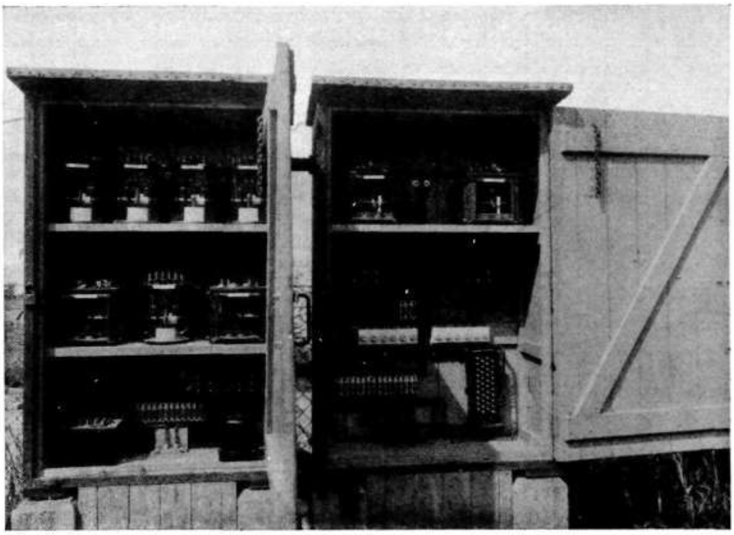


Fig. 3. Automatic block post on the Almedal Line.

When a train from Almedal has entered the southern section, signals 1va or 1vb cannot show "proceed" until the train has arrived at Gothenburg C or the goods station. For trains from Gothenburg towards Almedal, on the other hand, 1va or 1vb can indicate "proceed" for a following train as soon as the first train has cleared the northern block section.

The signal arrangements for the Almedal Line thus allow shorter intervals between following trains than between opposing trains. The arrangements used are made on the same principles of wiring as the well known A. P. B. block system for single lines.

The Passenger Station.

The station is of terminus type with making-up tracks for the trains to one side of the arrival and departure platforms. Between the making-up yard B and the platforms there is a special smaller yard F, for mail and express parcel coaches, which are often run with passenger trains. As the number of platform tracks is small compared to the number of trains and incoming and outgoing lines, the trains must not be kept longer at the platforms than is necessary for the passengers to get on or off. Incoming trains that are not due to leave immediately after arrival should therefore be moved over as soon as possible to the making-up yard, and outgoing trains be brought to the platform as shortly before departure as possible.

Figs 4a and b show graphically how the platform tracks have been used for the time-table in force in 1930, when the station was put in use, and for the present time-table. The time is marked by a vertical line for each hour of the day, and each platform track is represented by two parallel horizontal lines. These latter are filled in at times when a train is standing on a platform track. The part filled in is terminated by a leaning cross line on the left for incoming and on the right for outgoing trains. When the train begins or finishes at Gothenburg C and has therefore to be brought to or from the platform track by shunting within the station limits, the part filled in is terminated by a vertical cross line on the left or right respectively.

Usually empty trains are moved between the making-up yard and the platform tracks via the draw-out tracks K, L, and M. When a train is shunted away from the platform, its own locomotive backs it into one of these tracks, generally K, whence it is backed by a shunt engine to the making-up yard B.

The locomotive is then moved as soon as possible to the shed unless it has to be taken to the local engine depot of the passenger station for taking fuel or water, or to be turned; or, as is often the case with electric locomotives, it goes to the waiting track A to wait there until the next train to use it is due to depart.

When traffic is particularly heavy it may hap-

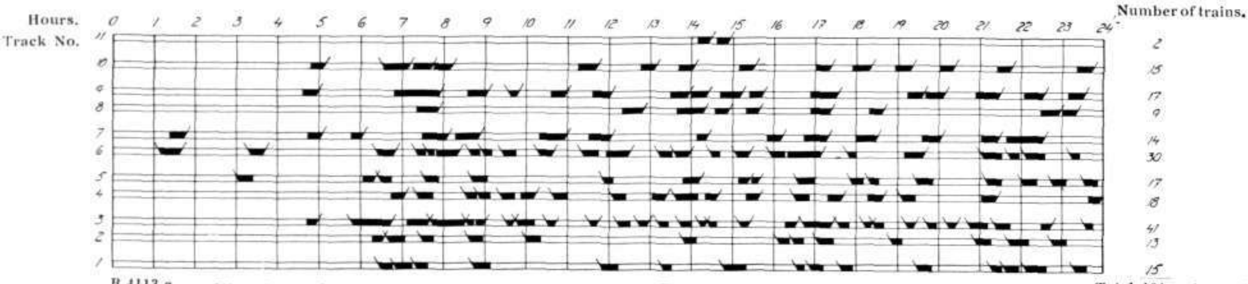


Fig. 4 a. Occupation of the platform tracks according to the time table 1930—31.

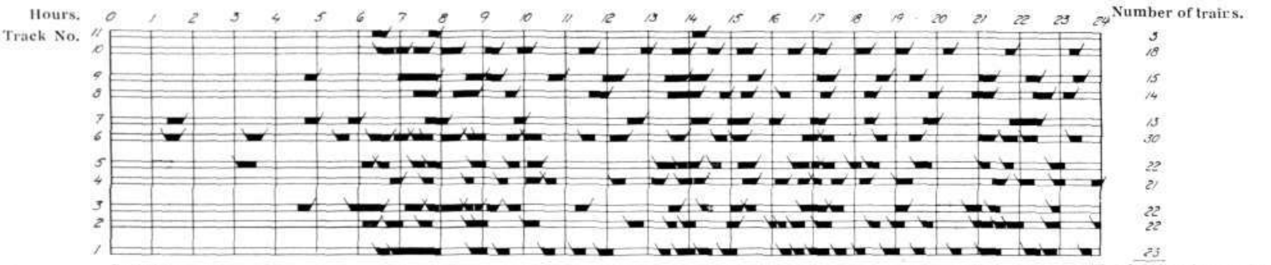


Fig. 4 b. Occupation of the platform tracks according to the time table 1931—32.

pen that none of the pull-out tracks is available. In this case the tracks O are used for storing empty trains until the traffic allows them to be shunted to the making-up yard.

Empty trains are usually moved from the making-up yard to the platforms via the pull-out tracks by shunt engines. The train locomotive is attached after the train has been brought to the platform. During busy hours new trains already made up can be stored in tracks O in order to release the draw-out tracks, which are occupied to a great extent also for rearranging trains in the making-up yard.

As far as possible locomotives arriving from the sheds go direct from the incoming line to their train if the latter is standing at the platform. If the train is not ready when the locomotive arrives, the latter is held on the track inside the incoming signal or moved to the waiting track A or to any other available track where it can wait for its train.

Local trains made up of electric rail motor cars generally leave after only a short stay in the station, during which the train is standing at the platform. Other local trains using a locomotive as tractive power are backed out from the platform track during their stay in the station, whereupon the locomotive is shifted to the other end of the train over suitable points, and finally the train backed to its departure platform.

A special category is formed by the large express and passenger trains which carry the traffic between the Continent and Oslo via the West Coast and Bergslagen Lines. These trains also have through-carriages from or to Gothenburg C, which have to be coupled to and fro during a short stay in the station.

There are also through coaches between the Western Main Line on the one hand and the Bohus and West Coast Lines on the other. These are moved from one train to the other by shunting at the ends of the platform tracks, while the trains are standing at the platforms.

Finally mail vans and express goods cars are shunted to or from the long distance trains, as well as cars carrying fish and other fresh goods, which are transferred from the harbour station to the passenger station via tracks B to be connected to passenger trains just before their departure.

From the above it will be seen that in designing the signalling arrangements, allowance must be made not only for train movements to and from the outgoing or incoming lines but also just as much for shunting operations within the station limits. Some mechanization of the signalling also for shunting movements was essential, to make it possible to deal with the expected traffic rapidly and without undue risk. It was therefore clear from the beginning that at Gothenburg C a system would have to be employed that would allow the use of fixed signals and interlocked points for the shunting movement as well, i. e. an installation similar to the one taken into use a few years before at Malmö, where traffic conditions are similar.

The division of the tracks into signal sections.

A shunting movement generally affects only a small part of the track system, while an incoming or outgoing train makes a continuous movement along the whole length of the yard between a platform track and one of the lines. In order not to impede other movements unnecessarily, the locking of points in shunting should not extend over a longer stretch at a time than is necessary for safeguarding the movement. The track lay-out was therefore, for signalling purposes, divided into sections, each of which was provided with signals for both entering and leaving.

The outgoing signal of one section is at the same time the entry signal for the next. Only sections ending with a dead-end track or leading to a siding, have no outgoing signals. The outgoing signals for the sections at the extreme end of the station are at the same time the entry signals for the block sections ahead.

Where a track branches off, one signal may serve as the entry signal for several sections. We find, for instance, in fig. 5 that signal 43h is for 5 different sections, ending at signals 53h, 51h, 49h, 47h and 45h. Similarly one and the same signal may be the outgoing signal for several sections meeting at that signal. 49h, for instance, is the outgoing signal for 3 sections, the entry signals of which are 43h, 39h, and 35h.

The determining of the positions and lengths of the signal sections is of course of great importance if the installation is to give good results, and should be done with careful attention to the demands of the traffic. The signal sections for inward and outward movements do not as a rule coincide either in position or length. The cost of construction increases with the number of signals, and the number of sections should therefore not be greater than necessary. Some of the principles employed in determining the signal sections at Gothenburg C are given below.

The station boundary, i. e. the outer ends of the sections next to the incoming and outgoing lines, has been pushed so far out that shunting may be done as a rule without affecting the use of the block sections. The departure of trains or single locomotives from Olskroken or Almedal is thus not interfered with by shunting operations in the station.

Each platform track is arranged as a separate signal section, the outgoing signal of which is placed at the fouling point behind the points at the outer end of the platform track.

The sections lying between the platform tracks and the station boundary have been determined by the position of the sets of points, which are drawn across the track system in two main directions. Movements in the cross-overs leading to the pull-out track K, which is generally used for moving empty trains to and from the platforms, ought to be possible with a minimum of disturbance from other movements. The signals were therefore grouped on either side of these cross-overs.

Draw-out movements from the platform tracks to move carriages from one train to another should be made as short as possible, in order to cause the least possible obstruction to other movements. The signal sections nearest the platforms are therefore made shorter than the others. When, for instance, coaches are being moved from track VI to track VII, they can be pulled out to signal 45va without interfering with movements further out in the track system.

Another advantage of having short sections at the ends of the platform tracks is, that a train for which there is not enough room in the signal section formed by the platform track will nevertheless be standing just inside a signal for outward movement. The platform track may be said to be extended by the short signal section adjoining it.

In all groups of points where a pull-out movement is often followed by backing the same set of cars, the signals are so arranged that there is always one available for showing "proceed" for the backward movement at the point where the pulling out movement usually ends. When a carriage is moved from track VII to track VI, signal 65va may for example be used for the pulling out and signal 65h for the backing in.

The division into signal sections is of course mainly a matter of judgement for which no exact rules of general validity can be given, and which must therefore be settled in each case according to local conditions.

The total number of signal sections within the station boundaries is 73 for inward movements and 84 for outward movements. Besides these there are the six block sections outside the station boundaries, which may be regarded as signal sections lying in the lines.

When a train arrives or departs it will pass several signal sections one after the other, the entry signals of which must each be at "proceed". It would of course be possible to let the movements of incoming and leaving trains be controlled entirely by shunt signals. This is also done in certain cases, namely, in the case of trains running on the double track against the normal direction of traffic, and trains on the Loop Lines, besides all cases where for some reason the whole route between the line and the platform cannot be cleared at once, e. g. for a locomotive going up to the platform track occupied by its train. Again, when a departing train is so long that its locomotive is standing outside the outgoing signal from the platform section, it must be moved in stages on the same signals as are used in shunting.

Movements in stages under control of shunt signals alone would, however, mean much loss of time to long and heavy trains, as they would then always have to be moved at comparatively low speed. Special signals have therefore been arranged for movements between the platform tracks and the incoming and outgoing lines generally used by the passenger trains enabling a "proceed" indication to be shown for the whole train route through the yard. All the signal sections on the route must then be clear and the signals for them showing "proceed". Such special signals are arranged for trains coming in from the Down, B. J., and Almedal Lines and departing from any of the platform tracks towards the Up, B. J. and Almedal Lines.

The track arrangements frequently allow of several routes for a train between a line and a platform track. In such a case the installation also allows for the use of any of these routes, that one to be chosen which can be used at the time of the train movement with the least possible interference with other simultaneous movements. Between the B. J. Line and track VI, for instance, there are three routes, viz. over points 66a, 36 or 54a. The total number of routes between the incoming and outgoing lines and the platform tracks is therefore greater than that indicated directly by the number of lines and platform tracks, being 52 for incoming and 57 for outgoing trains, instead of 30 and 33, as it would be if for each line there were only one arrival and one departure route per platform track.

The division of the tracks into track circuits.

Besides signal sections, the tracks have also to be divided up into insulated track sections or track circuits, the function of which is to effect that part of the signalling whose object is to show if the route is free of obstruction, i. e. clear of vehicles, to a shunting or train movement. The track circuits must further prevent the points being operated too early, either just under a vehicle standing over a pair of points when a derailment certainly would occur—or just in front of a movement, which otherwise might be turned on to a different track from the one intended. Track circuits also serve to prevent a second movement taking place before the first one started has been safeguarded.

The division into track circuits is shown in fig. 5, where the limits between them are indicated by a break in the track. Track circuits are denoted by an S, followed by the number of the points in the track circuit or, where there are no points, the name of the track or the number of the signal at the inner end of the track circuit. This symbol is printed in the plan only when referring to a signal number or a track.

A division between two track circuits is always located opposite or quite close to every signal. A signal section may, however, include several track circuits. The divisions between these are often placed at rail joints in front of points or opposite fouling points between converging tracks. In the parts of the lay-out where shunting is frequent and the lengths of these movements therefore ought to be limited as far as possible in order not to hinder simultaneous movements, the track circuits have been made shorter than elsewhere. This is, for example, the case at the ends of the platform tracks.

Considering the cost of installation and maintenance, an increase in the number of track circuits is a disadvantage, and the division must therefore not be carried further than the traffic conditions make necessary. The dividing into track circuits is mainly a matter of experience and judgement, and greatly affects both the economy and the usefulness of an installation.

Fig. 6 shows part of the track lay-out on a larger scale, so that the position of insulating rail joints and connectors between the rails can be seen. The two rails opposite one another in a track circuit must not be in metallic contact. All the tie-plates and connecting rods between the rails at the points must therefore be provided with insulated joints, which are made by having the plates and rods made in two parts separated from one another by packings of vulcanized fibre. One of the rails of a track circuit is called the plus, the other the minus rail. The same polarity must not prevail in rails opposite one another for a length of track greater than the minimum distance between the axles of the vehicles. At Gothenburg this length in no case exceeds 1.5 or 2 m.

The length of a track circuit ought to be greater than the max. distance between axles on the vehicles, as, when a train is passing, the plus and minus rails must be in constant connexion through the wheels. The shortest track circuit at Gothenburg is 17 m.

Only the plus rails of two adjoining track circuits have been separated by insulating rail joints, the minus rails being metallically connected with one another to serve as return conductor for the traction current.

The total number of track circuits within the station boundary is 65, that in the outside lines 10. Frequency-selective vane relays, Westinghouse Type L, are used as track relays except in seven circuits which are not affected by the currents of the electric trains. The frequency-selective relays are immune to the frequency of the traction current, $16\,^2/_3$, and are fed with a 50-cycle signal current via condensers and inductive track transformers, so that the supply of current is practically constant. The principles of this device are described in an article in the L. M. E. Review 7—9, 1931. Relay transformers of ratio 1 : 4 are connected between the track and the relay to reduce the voltage drop in the long cable conductors to the relays, all of which are located in the signal cabin.

Interlocking of the levers in the locking frame.

Tables I and II give extracts from the locking tables prepared for this installation. To make the tables clear it may be mentioned that points and signals are denoted by the numbers of the levers with which they are operated. Even numbered levers are used for the points, odd numbered for the signals. When two pairs of points are operated by the same lever only one number is given in the table, but in the plan these points are distinguished by the letters a and b after the number. A letter h or v after the number of a signal means that the signal is operated by moving the signal lever to the right *(höger)* or left *(vänster)* respectively. The former is used for inward, the latter for outward movements. Thus in clearing the signals the levers are moved in the direction of the train movement, which makes the arrangement easy to survey and facilitates operation.

Before a signal can be cleared, the point levers must first be brought into proper position for one of the signal sections beginning at the signal. If the position of a point does not correspond to the position of the lever in the cabin, it must be impossible to show "proceed". When the signal lever is reversed, the point levers in the signal section are locked in their proper position and interlocking is then said to be arranged between the signal and point levers. Further, it must be impossible for the signal to be cleared if a "proceed" indication has already been shown for any conflicting movement, by which is meant a movement in another signal section having some tracks common with the first one. This is prevented either by direct interlocking between the signal levers or by locking some suitable points, safety points, in positions preventing entry to the signal section to be protected. The locking of safety points is not always possible, but has been used in this installation as far as admitted by the track lay-out and by practical considerations in general.

Movements across the track just outside the signal section run the risk of a collision should the movement for which the signal is to be cleared not be stopped at the outgoing signal of the section but slip over into the next section, and are therefore regarded as conflicting. Such movements crossing the track just outside the signal section have been prevented by locking

TABLE I

Lever	With	Requires	Unless
25h		13v, *43h*	
»	26, 38	*53h*	
»	26, *38*, 40	48, *51h*	
»	26, *38*, *40*	46, *49h*	
»	26, *38*, *40*, *42*	*66*, *67h*	
»	26, *38*, *40*, *42*	*72*	68/70
»	*26*	44	
»	26, 32	*47h*, *66*, *67h*	
»	*26*, 32	*72*	68/70
»	*26*, *32*	*45h*	
»	*26*, *32*, 36	*67h*	
»	*26*, *32*, 36	*72*	68/70
»	*26*, *32*, *36*, 56	*65h*, *72*	
»	*26*, *32*, *36*, *56*	*59h*, 60	

Lever	With	Requires	Unless
41v		26, 38/*38*, *40*	
»	38	23h, 28, 39h	
»	*38*	25v, 43h	
43h		26/*26*	
»	26	38/*38*, 53v	
»	26, 38	48	
»	26, *38*	40/*40*, 41v, 51v	
»	26, *38*, 40	46	
»	26, *38*, *40*	37v, 42/*42*, 44	
»	26, *38*, *40*, 42	49v	
»	26, *38*, *40*, *42*	47v	
»	26, 38, *40*, *42*	67v	66
»	*26*	*28*, *30*, 32/*32*, 33v, 34	
»	*26*, 32	42, 44/*44*, 47v	
»	*26*, 32, *44*	49v	
»	*26*, 32, *44*	51v	46
»	*26*, 32, *44*	53v	46/48
»	*26*, 32, 44	67v	66
»	*26*, *32*	36/*36*, 45v	
43v		25v, 26, 38	

TABLE II

Lever	Requires	Unless
14	*16*	
16	14, 18, 22, 34	
18	16, *20*, 22	
20	18	
22	16, *18*, 32	
26	*28*	
28	26, *30*	
30	28, 34	
32	22, 34, 44	
34	16, 30, 32, *44*	
36	66	
40	44	
42	44, 46	
44	32, 34, 40, 42, 65	
46	42	
50	52, 56	
52	50, 54	
54	52, 56	
56	50, 54	
58	60	
60	*58*	
64	70	
66	*36*, 44	
68	70	
70	64, *68*	
4	12	
10	24	
12	4	
24	*10*	

Lever	Requires	Unless
16	29h, 55h/v	
»	45v	*32*
18	55h/v, push-button 55t	
20		
22	29h, 45v, 55h/v	
»	33v	34
»	57v	*50*
»	65v	*50/54*
26	23h, 33v, 37v, 39h, 41v, 43h/v	
»	45v	32
28	33v, 39h	
»	35h	*12*
»	37v, 41v	*38*
»	45v	32
24	33v	22/34
»	45v	22/32
»	55v	*16*
»	55h	

trailing points also beyond the signal section. The trailing points have been locked over the whole of the next signal section whenever demanded from the safety point of view. For movements from the platform tracks, the risk of pulling out past the outgoing signal of the section was not important, and, as the locking of all the trailing points in the next section would restrict other movements too much, it was for those movements considered sufficient to lock trailing points within a distance of 50 m. from the end of the signal section. This would, for instance, allow movements in the cross-overs leading up to track K to be made independent of movements in, for example, the signal section 65va—45va, as the distance between the outgoing signal 45va and the fouling point behind points 34a is about 50 m.

In a few cases a ground signal of the type used in connection with scotch blocks has been mounted at the fouling point between converging tracks and so connected with the points that the signal shows "stop" for the main track when the points are reversed. Behind points 26a there is such a signal, which allows the points to be free for movements on, for instance, signal section 53v—43v. For the section 43v—13v, which contains points 26a, these are of course locked in spite of the ground signal.

Signal levers for routes direct between the lines and the platform tracks are made to depend on the signal levers for all the signal sections of that route, so that the latter levers must be reversed before the first ones can be operated. This locks the levers of the sections in the reverse position, and they cannot be restored to normal unless the lever of the direct route has first been put back.

Looking at table I, we find on the right examples of interlockings for a signal lever (43h) connected with a signal for a signal section, and to the left for another signal lever (25h), connected to an incoming main signal from a line to a platform track.

The table for 43h reads as follows, line by line:

The reversal of lever 43h to the right requires point lever 26 to be at + (normal position) or — (reverse position);

with point lever 26 at +, 38 to be at + or —, and signal lever 53v not to be reversed to the left;

with 26 at + and 38 at +, 48 to be at +;

with 26 at + and 38 at —, 40 to be at + or —, and 41v and 51v not to be reversed to the left, etc.

The table for lever 25h reads line by line as follows:

When lever 25h is reversed to the right, 13v must not be reversed to the left, but 43h must be reversed to the right;

with 26 and 38 at +, 53h to be reserved to the right;

with 26 at +, 38 at —, and 40 at +, 48 to be at +, and 51h to be reversed to the right etc.

Table II shows on the right how the point levers are locked by the signal levers. For point lever 28 the table gives the following lockings:

of 33 and 39 always;
of 35h unless point lever 12 is at —;
of 37v and 41v unless 38 is at —;
of 45v unless 32 is at +.

A special kind of locking is sometimes arranged direct between the point levers, so that these must be operated in a definite order. This kind of interlocking will to some extent simplify the arrangements, but may on the other hand necessitate points being operated simply to release point levers, thereby increasing the number of point operations. In a busy station this is a disadvantage and may, when in a snowstorm snow and ice render the operation of points difficult, add to the difficulties of keeping the traffic going. In view of this, interlocking between point levers has at the Gothenburg installation, as well as at other similar installations on the State Railways, only been employed where obvious advantages from the safety point of view are thereby obtainable without complicating the operation of the points.

The principles followed in using this kind of interlocking at the Gothenburg installation may be made clear by some example. For this purpose we will again refer to the diagram in fig. 5.

Points 26b and 28a form together a single slip switch. For all movements with points 26 at minus it is necessary for points 28 also to be at minus. The levers of these points have therefore been interlocked so that 28 always has to be reversed before 26 can be reversed. The removal of the points to normal must then be effected in the reverse order.

Before reversing point lever 4 12 must be at normal, because points 12 must always be at plus when a movement takes place with points 4 at minus.

At a double cross-over, as between points 50a and b, and 52a and b, the point levers are interlocked so that only two pairs of points at a time can be brought in position for movements through the crossing.

When points 18 are set for movements from track K into the running lines, 20 must first be set to track L, so as to serve as safety points for these movements.

On the left in table II, examples of direct interlocking between point levers are shown.

Locking by track circuits.

Track circuits are used in the installation to lock signal levers in reverse positions, *route locking*, and for direct locking of point levers, *point locking*.

The levers of signals governing movements direct between the incoming and outgoing lines and the platform tracks are equipped with route locking, which works in the following way. On reversing the signal lever it becomes locked in the reverse position and cannot be restored to normal until the train has passed over the route and entered the last track circuit of the route, i. e. the track circuit of the platform track for incoming trains, or the track circuit nearest to the block section for outgoing trains. The signal lever has to be restored after each train, as it is arranged that otherwise "proceed" cannot be shown for a following train.

Should it be necessary to restore the lever and change the route without a train having passed, the lever can be released by means of a time switch. The signal must then show "stop" for a suitable length of time before the signal lever can be brought into such a position that the point levers of the route are free to move. This time-switch is also used, should the devices for automatic release of the route fail to function. A sealed switch for emergency release could therefore be dispensed with. The time switches are of the same type as those used for the line block sections and have been installed for routes to and from the Up, Down, B. J. and Almedal Lines.

Route locking can only be used where the clearing of a signal is followed by a continuous movement from one end of the route or signal section to the other. This is not the case in shunting, as every movement cannot be expected to pass the whole signal section, but might stop within the section and continue in the opposite direction. The levers of the signal sections are therefore not provided with route locking, but are left free to restore to normal at any time. Point locking is therefore arranged to prevent points in a signal section being operated before this can be done with safety.

Two different methods of point locking, one *direct* and one *indirect*, are used in this installation side by side, supplementing one another. By the first method the point levers are locked as long as certain track circuits are shunted by vehicles. The locking is effected by contacts of the track relays directly breaking the current to the lock magnets of the point levers. The following track circuits are considered for such locking of point levers.

Track circuits in which points connected to the lever are situated, e. g. S26 and S26/28 for point lever 26;

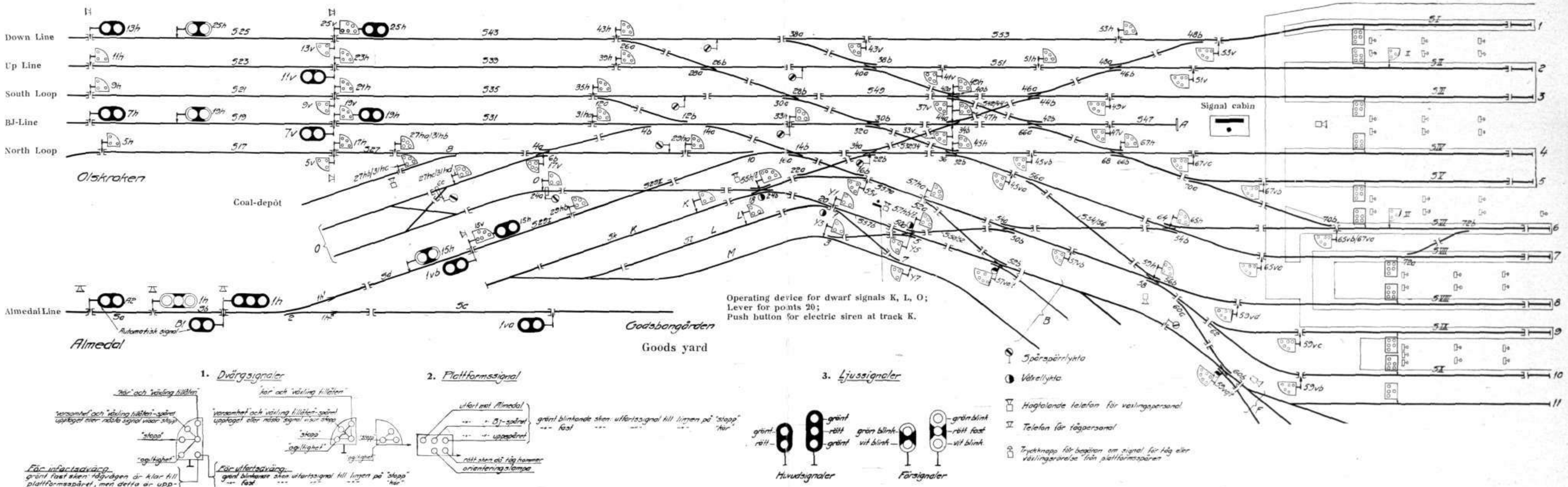
the track circuit between two pairs of points connected to the lever, e. g. S54/56 for lever 56;

track circuit behind a pair of points connected to the lever, when wanted to prevent the throwing of the points until a previous movement has passed clear of the fouling point, either behind a shunt signal showing "stop" for movements towards the points or behind a pair of points which can be laid in a position to prevent such movements, e. g. S49, S28/30 and S12a for lever 40; S32/36 and S30/32 for lever 34;

track circuit situated in front of a pair of points connected to the lever when wanted to prevent the points being operated before a signal controlling movements in the opposite direction has been passed, e. g. S12a for lever 30, or when a vehicle is immediately in front of the points, e. g. S57b for lever 20.

The direct method of point locking acts independently of the direction of movement, but may be changed by varying the positions of other points. The locking between S12 and lever 40 for instance does not function if point lever 12 is reversed.

By the second, indirect method, the locking of the points only takes place if a vehicle enters the signal section with the lever for the incoming signal of that section in reverse position. The locking is effected by means of special lock



1. Dwarf signals.

"Proceed" and "Shunting allowed".
"Caution" and "Shunting allowed"-track engaged, or next signal at "stop"
"stop"
"neutral"

For incoming dwarf:
Green steady light: route clear to the platform track, which is occupied.

"Proceed" and "Shunting allowed".
"Caution" and "Shunting allowed"-track engaged, or next signal at "stop"
"stop"
"neutral"

For outgoing dwarf:
Green flash light: entry signal to the line at "stop".
" steady " " " " " " " "proceed".

2. Platform signals.

Departure towards Almedal
" " BJ-Line
" " Up-Line
} Green flash light: entry signal to the line at "stop".
" steady " " " " " " " "proceed".

Red light when train arrives.
Marker light.

3. Light signals.

	green		green flash light
green	red	green flash light	red steady "
red	green	white " "	white flash "
Main signals		*Distant signals*	

Scotch block lamp.
Point lamp.
Loudspeaking telephone for shunting staff.
Telephone for train staff.
Push button for requesting the signal for a train or shunting movement from a platform track.

Fig. 5.

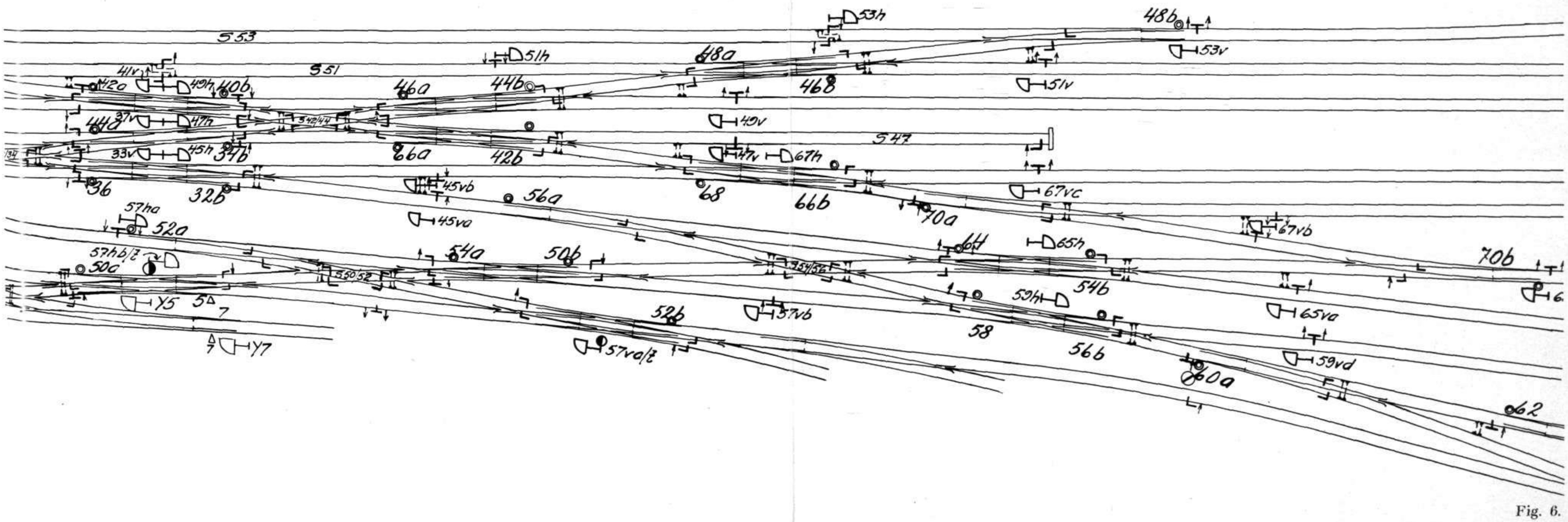


Fig. 6.

relays and functions differently according to the direction of movement. The use of this locking method is best explained by an example.

Supposing signal 45va has been cleared for a movement into the signal section between 45va and 9v over points 30. Point lever 30 is made dependent on a relay which starts locking the lever at the moment the signal is passed by a vehicle. Even if the signal lever is restored to normal immediately the signal has been passed, the relay will continue locking the point lever until the track between signal 45va and points 30 b is free of vehicles. The purpose of these lock relays is thus to prevent points being operated while movements are going on between the incoming signal of the signal section and the points, i. e. until vehicles have entered one of the track circuits directly affecting the point lever by the direct method of point locking.

Fig. 7. Dwarf signals.

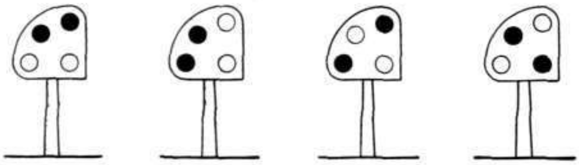
Point locking requires the use of quick releasing track relays in which the contacts will open at practically the same moment as the track circuit is shunted by a vehicle. But if a signal is put back from "proceed" to "stop", and a pair of points just behind the signal are thrown over immediately afterwards, there may still be the risk of derailment at the point, if a locomotive just in front of the signal has observed the proceed indication and started moving towards the points, and has afterwards failed to notice the stop indication, or, after noticing it, has not been able to stop at the signal. Point locking by means of the lock relays would also be out of action should the signal lever be restored before any vehicle has passed the signal.

To prevent this, some signal levers have been fitted with a delaying device which, if there are vehicles on the track circuit in front of the signal, will act so that the lever cannot be restored directly from reverse to normal but has to be kept in an intermediate position for a certain time after the signal has occupied the "stop" position. During this time the points remain locked. A delay does not occur if the track circuit in front of the signal is free. Loss of time on account of the delaying device will thus only result if a proceed indication after being given has to be cancelled while there are still vehicles on the track circuit in front of the signal. This device has only been considered necessary for some ten signal sections situated rather far away from the cabin, where movements are hard to survey from the cabin. The delay is obtained by special relays with a clock-work arrangement of the usual type. The signal lever is locked by a back contact of the corresponding time relay, this contact being opened when the relay, on reversal of the signal lever, is energized. The contact is shunted by a front contact on the track relay of the track circuit in front of the signal, the delaying device thereby being out of action when that track circuit is free.

For route locking and indirect point locking, D. C. relays of the L. M. E. standard type have been used, with 4 front and 4 back contacts, and a 2 000 ohm coil for 12 V. There are 37 of these relays, of which 16 are used for route locking for arriving and leaving trains and 21 are lock relays for point locking.

Signal aspects.

As incoming and outgoing signals for the signal sections within the station dwarf signal according to the safety regulations of the State Railway were to be used. Such a signal is illustrated in the regulations with the figure shown in fig. 8 and described as follows:—



R 4116 Fig. 8.

"Dwarf signal: a lamp device from which are shown 2 steady white lights either in a horizontal line (a), or in a vertical line (b), or in a line sloping at an angle of 45° to the left (c) or to the right (d), the lights to be visible in daylight also."

The signal aspects "b" and "c" in fig. 8 should be understood as an authorisation from the signal men in the cabin to carry out some intended movement. The shunters and drivers have to make use of this permission as soon as possible, thereby enabling the signal men to determine the order in which the shunting operations are to be performed. The aspect "c" means a restriction of the proceed indication so far as the signal may be shown even when the signal section ahead is occupied. This aspect therefore means "caution" and only makes sure that the points are in proper position and that signals for conflicting movements indicate "stop". The aspect "c" will always appear on reversal of the signal lever unless the following conditions for showing aspect "b" are already satisfied.

For aspect "b" to appear there is the additional condition that the whole signal section must be clear of vehicles. If there is an outgoing signal from the signal section that one must also show "proceed" or "caution (aspect "b" or "c"). If these conditions are fulfilled aspect "b" will appear automatically instead of "c" without any special action of the signal men. Aspect "b" is not used for signal sections leading on to make-up tracks where there are no track circuits, for example, when a movement is to be made on signal 57ha to tracks B or F. Nor will indication "b" appear for movements towards the short waiting track A.

Position light signals as in fig. 8 have also been used for controlling movements on the Loops, and for movements against the normal direction of traffic on the Up and Down Lines. These signals only show the aspects "a" and "b", i. e. "stop" and "proceed", the latter requiring the whole block section to be clear of vehicles.

Aspect "d" (neutral) has been used in this installation for controlling movements which are not supervised from the signal cabin. This is the case with all movements between tracks O, K, L, and M on the one hand and B and F on the other, i. e. shunting movements taking place outside that part of the lay-out which is used by incoming and outgoing trains. Therefore, signals 55h/t, 57hb/t, 57va/t, and 59va/t show the neutral aspect for movements not leading on to the running lines. When this aspect is to be shown, the lever normally used for the signal section must not be reversed, but a special switch, mounted on the frame above it, used instead.

The neutral aspect is automatically controlled by the position of the points which must then be diverging from the running lines.

The neutral indication is also used on dwarf signals O, K, and L, which are intended to prevent simultaneous movements towards points 24b and 20 from tracks O, K, and L, and on signals Y 1, Y 3, Y 5, and Y 7, the object of which is to prevent simultaneous movements through the cross overs 1—7 and 3—5 when the points are so set that a collision may occur between crossing movements.

Signals O, K, and L are selected automatically by the position of points 20, 24, and 18, but may be set to "stop" either by a lever in the signal cabin or by a lever at a place near points 1, 3, 5 and 7. These latter are always operated on the ground. Normally, points 20 are connected to the signal cabin, but they can also be operated on the ground by means of a ground lever near the points just mentioned (dual electric control). Points 18 and 24 are always operated from the signal cabin.

The aspects of the signals Y depend on the position of the points 1, 3, 5, and 7. "Stop" appears automatically when movements must not take place; otherwise the neutral aspect is shown. Y 1, for instance, indicates "stop" when points 3 or 5 are reversed, or when points 1 are at plus and 7 at minus or vice versa.

While thus position light signals are used for movements on the signal sections within the station limits and on the Loop lines as well as for movement against the normal direction of traffic on the double track, colour light signals are used for movements direct from the block sections to the platform tracks. In the safety regulations of the State Railway a colour light signal is illustrated by the figures shown in fig. 9 and described as follows:

Fig. 10. Incoming and outgoing signals for the Olskroken Lines.

"*Light signal*: a lamp device which can show a red light, steady or *flashing, or else one*, two, or three steady green lights placed vertically above one another, all lights visible also in daylight."

Note 2. Such a light signal may be arranged to show also a flashing *green or white light*, then assuming the function of a distant signal.

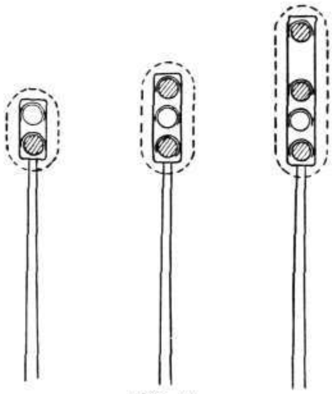


Fig. 9.

Note 3. The main signal allowing trains to enter a station is called the incoming signal, to leave a station the outgoing signal.

A steady green light is used in the installation as proceed indication on the incoming signals. The speed-limit for all movements through the station being 40 km. p. h., and all routes beeing practically equal in length, different signal aspects were not required for indicating the speed. Nor was it considered necessary to indicate at the incoming signal the platform track to which the train should proceed. While the train is passing through the yard a certain direction as to the route is, however, obtained by means of the dwarf signals of the various sections of which the route is made up.

A light signal with two different proceed aspects is used on the entry signal (1h) to the southern block section of the Almedal Line, to show if the route is cleared to Gothenburg C or to the goods yard. One green light is used for the former, two for the latter.

The incoming signals from the Down, B. J., and Almedal Lines are provided with distant signals, which are described in the regulations as follows:

"Light signal: a lamp device by means of which a green or white flashing light (in some cases also a red light, steady or flashing) is shown, all lights to be visible in daylight also."

The distant signals were mounted about 300 m. from the incoming signals. This short distance was considered convenient because the speed of the trains had to be reduced already before entering this terminus, in which the maximum speed is limited to 40 km. p. h.

Further, it was considered that the incoming signals ought to be cleared as short a time as possible before the arrivals of the trains in order not to cause unnecessary delay to other movements in the yard. If the distant signal were placed too far from the incoming signal, the signals would generally not be cleared until after the train had passed the distant signal. That being the case, the benefit of the distant signal would be illusory.

The block signal 1h on the Almedal line was

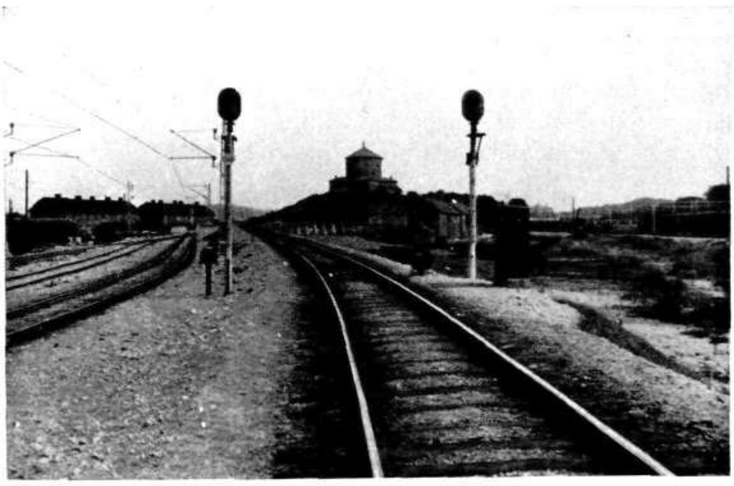


Fig. 11. Incoming and outgoing signals for the Almedal Line.

Fig. 12. Dwarf signal at platform track.

provided with a distant signal at a distance of 700 m., full line speed being allowed here. This distant signal was also provided with a red light, which is shown when a train is moving in the direction of Almedal, or when there is a train on the track circuit between 1h and the distant signal.

It would of course have been possible to use light signals as in fig. 9 as outgoing signals for trains going direct from the platform tracks towards the lines. But as in this case the signals are given to a train standing at the platform, it was considered sufficient to provide the dwarf signals already existing at the outer ends of the platform tracks with a special signal aspect with the object of showing when a route is clear from that platform track to a block section. The signal consists of a green light placed immediately below the lower right-hand light of the dwarf signal. This green light will appear together with aspect "b" when a route is clear up to the entry signal of the Almedal, B. J., or Up Line. A flashing green light is shown when the entry signal is at "stop" and a steady green light when the signal shows "proceed". A train can leave the platform track even though a flashing green light is shown, but must then proceed with caution and be prepared to stop at the station boundary, should the entry signal to the block section still be at "stop" when the train reaches it. The route through the station is thus treated as a line block section, into which a train can be admitted before a previous train has arrived at Olskroken or passed the southern block section of the Almedal Line.

A signal of the type used for outgoing trains has in some cases been used at Gothenburg C for incoming trains also. It was necessary to be able to admit a train to platform tracks II or VI while a short train was still standing at the platform. Special dwarf signals, indicated in fig. 5 by II and VI, were therefore fitted about half-way down these platform tracks, the signals normally showing the neutral aspect. When the first train has arrived behind this signal the platform officer (the train clearer) will set the platform signal to "stop". This enables the signalman in the cabin to direct a new train to the platform track although this is already occupied. The clear signal will then not be given with the main incoming signal, but with a green light on the dwarf signal underneath the incoming signal, which shows a red light all the time to indicate that the movement is directed against a train already standing at the platform.

Signals of a special kind are those put up at the platforms, in order to announce to the platform officer and other platform staff that a proceed signal has been shown for a train to leave or enter the station. There is one of these platform signals at each platform track. The signals face the platform and each one has three green lights and one red, besides a white marker light.

When proceed is shown for an outgoing train to leave the station, one of the green lights is switched on. The left-hand light indicates departure towards the Almedal Line, the middle one towards the B. J. Line, the right-hand to the Up Line. The platform officer has to check the indication to see that it is for the right line, before he gives the driver the order to start.

The red light of a platform signal is switched on when an incoming signal is cleared for a train to enter the platform track in question. The red light means that a train is expected, and serves to call upon porters and other staff concerned to turn up on the platform to receive the train.

In each platform track the last 30 m. next to the buffer stops have been left without a track circuit, so that vehicles can be standing there when a train arrives. For these, and also for trains standing at the platform when another train enters the same track, the red light means "stop".

Fig. 13. Platform signal.

The signal cabin.

The principal connexions between the tracks of this yard being the set of points ending at the platform tracks, it was quite natural to centralize the operation of the signals and points to a single cabin. This ought to be placed at a suitable spot near the platforms used by the long distance trains, where a direct supervision of the shunting movements appeared to be most wanted.

At first it was intended to build the signal cabin in three storeys, of which the ground floor would be used for the power plant, the first floor for the relays, etc., and the top floor for the interlocking frame itself. It was, however, found necessary to prepare for a future extension of the platform beyond the place between tracks III and IV which had been reserved for the signal cabin. The ground floor therefore had to be dispensed with and replaced by columns to carry the building. The lower part of the building had to be reduced in width at the same time, to allow free passage along the future platform on both sides of the building. After this reduction a width of slightly more than 2 m. could be used for the first floor. It was not possible to make the building higher to compensate for the loss of the ground floor, the subsoil being very unsuitable for a high building. It was therefore decided to

Fig. 14. The signal cabin.

make only two floors, as it proved possible to find room for the necessary apparatus by careful disposition of the available space.

The top floor was made wider, projecting beyond the first floor as far as the 16 000 V trolley wires of the electric traction allowed. Thus a width of about 4.5 m. was obtained for the top floor.

The length of the building had to be chosen according to the floor space necessary on the first floor, and it was therefore made longer than was necessary for the interlocking frame, the length of which was only 6 m. The length of the cabin was thus made about 14 m., which allows for a considerable extension of the frame in the future.

Besides the interlocking frame and other apparatus requiring the direct attention and supervision of the signal men, all the switch-boards for the power supply, as well as the rectifiers and some of the transformers and resistances, were placed on the top floor.

On the first floor were placed a rotary converter and the larger transformers; also the end boxes and distribution panels for the underground cables coming into the cabin, and finally a relay shelf to carry the relays, etc. The disposition of the available space appears from the cross sections of the signal cabin shown in fig. 17.

The interlocking frame.

The motors of 57 points and 2 scotch blocks were to be controlled from the frame. The majority of the points belonged to cross-overs between parallel tracks, and could in most cases be combined in pairs on the same point lever, only 9 points requiring separate levers. In addition, one lever was required for locking the points in a cross-over between platform tracks VI and VII, the points of which were to be operated from the ground and only locked from the cabin on train movements on those platform tracks. The total number of levers required for points and scotch blocks was 35.

In addition, 55 dwarf signals, 10 main incoming signals and 11 outgoing signals, 76 signals in all, had to be operated from the frame.

The number of routes for shunting movements was 157, for train movements within the station limits 109, and for the lines 13, or a total of 279.

Owing to the large number of routes, an interlocking frame with the German type of locking register, in which not more than two route combinations can be connected to the same lever, was considered out of the question. This kind of interlocking frame would have needed at least 150 signal levers which would, with the 35 point levers and necessary spare levers, have necessitated a length of 16 to 18 m.

With the American type of interlocking register the number of signal levers is not fixed by the number of routes but by the number of signal units operated from the frame. The number of signal levers is thus not increased if, as is often the case, the same signal is used for a number of different routes. Each signal lever corresponds to a certain signal or group of signals. In this case the number of signal levers required was less than a third of what a German register would have needed.

The difference between the two types of register lies in the method of interlocking the signal levers and point levers. In a German register the locking pieces are always firmly fixed to the locking bars, which are only used with signal levers. Each locking piece will always affect a certain other lever in exactly the same way. The reversal of a signal lever therefore always presumes the same relative position of the points, i. e. the same route.

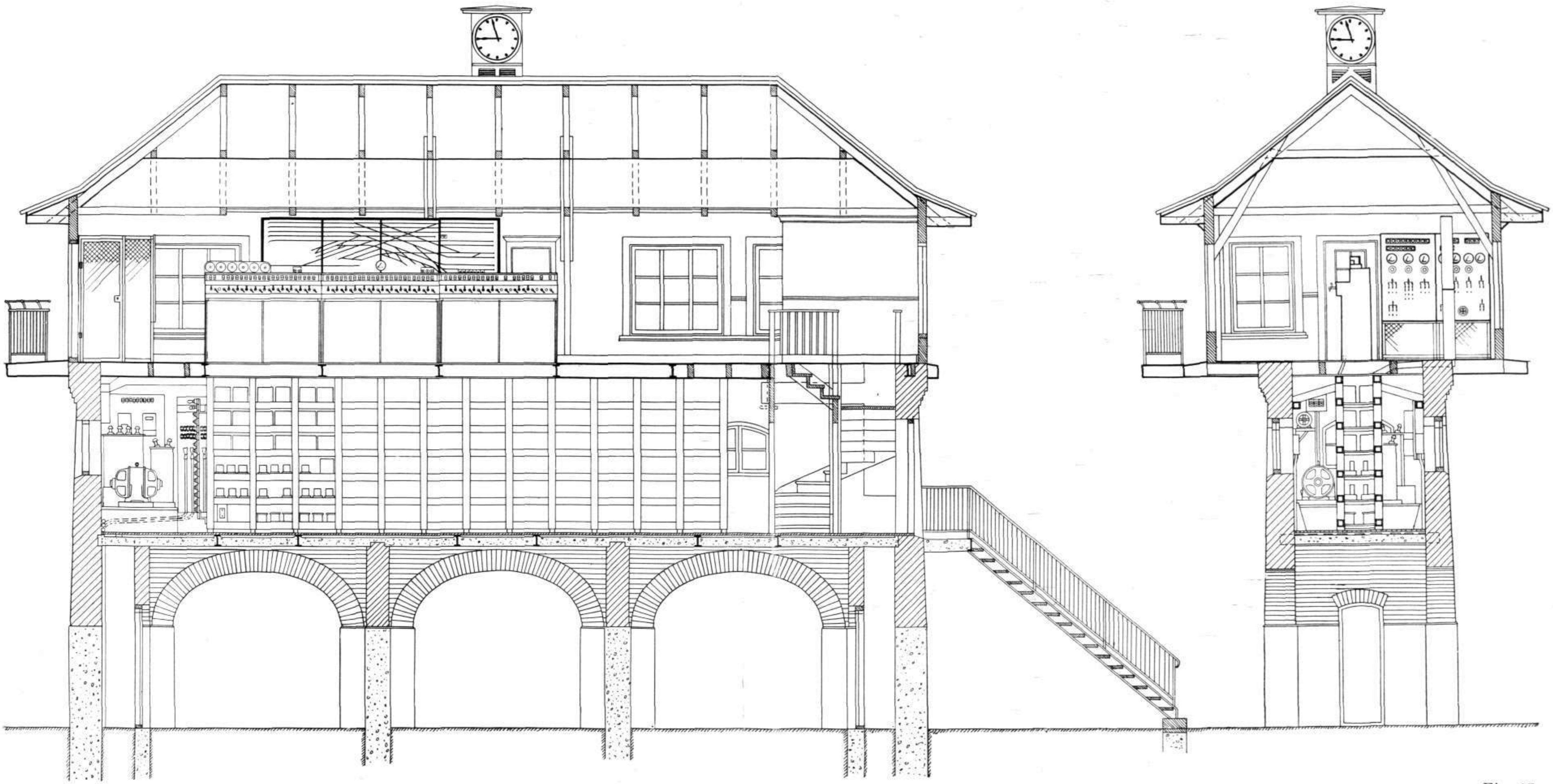


Fig. 17

Fig. 15. The top floor of the signal cabin.

In an American register also the point levers are provided with locking bars. The levers are interlocked by means of locking pieces which are movable relative to the locking bars. The same locking piece may be affected by several different levers, and also lock several different levers. When a signal lever is reversed, the point levers are locked in position for one of the routes to which the corresponding signal applies. Such locking of several routes by the same lever is rendered possible by what is called the conditional locking typical of this kind of register, which enables levers to be locked only if one or more other levers are in a certain position. According to the interlocking table, conditional locking is required for every combination showing lever numbers under the heading "with" or "unless".

American registers of two different designs had so far been used on the State Railway, viz. one with a plain mechanical register, as at Malmö (L. M. E. Review No. 1—2/26) and one with an electro-mechanical register, as at Hässleholm and Lund (L. M. E. Review No. 1—3/27, 10—12/30). The latter type of register was selected for Gothenburg C also. The final reasons for this were the considerably smaller first cost and the lower maintenance costs due to the elimination of the complicated mechanical register. Another advantage of importance is the greater ease with which alterations and extensions can be made with an electric register. Finally, such a register required considerably less space, as will be seen in comparing the cross sections shown in fig. 18 of the Gothenburg interlocking frame and various frames with mechanical registers of the size needed for this station.

The interlocking frame was provided with 72 levers, of which 30 were signal levers, 35 point levers, and 7 spare levers. The design of the frame is that described in the L. M. E. Review, No. 1—3/31. The point machines are of the type described in the L. M. E. Review, No. 10—12/1931, with motors for 120 V. D. C., controlled by contacts on the horizontal axles of the point levers.

The positions of the points are checked by Westinghouse Type G2 three position relays with local and indicating windings for 110 V, 50 cycles, all the relays being located in the cabin. Each relay has 6 normal and 6 reverse contacts, and there are 35 of them, i. e. one relay for each point lever.

The signals are operated by means of relays of L. M. E. standard type with 4 front and 4 back contacts, and a 2 000 ohm coil for 12 V. D. C.

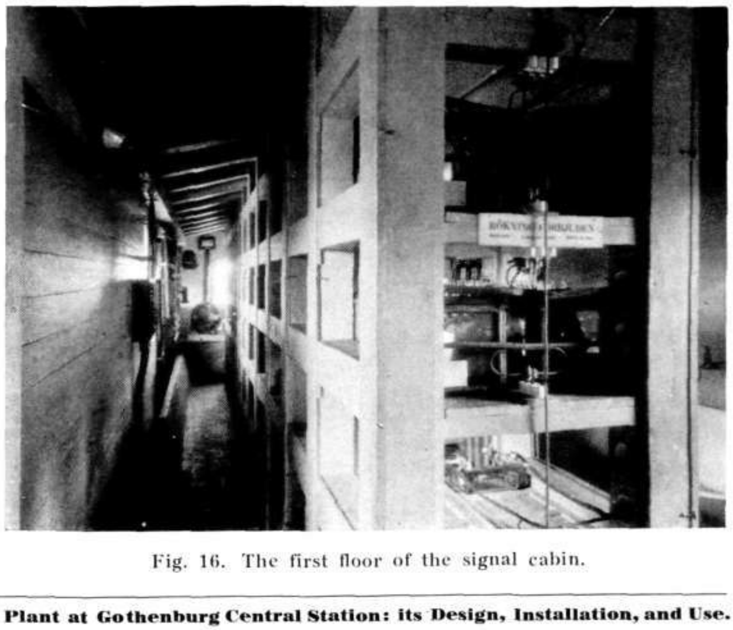


Fig. 16. The first floor of the signal cabin.

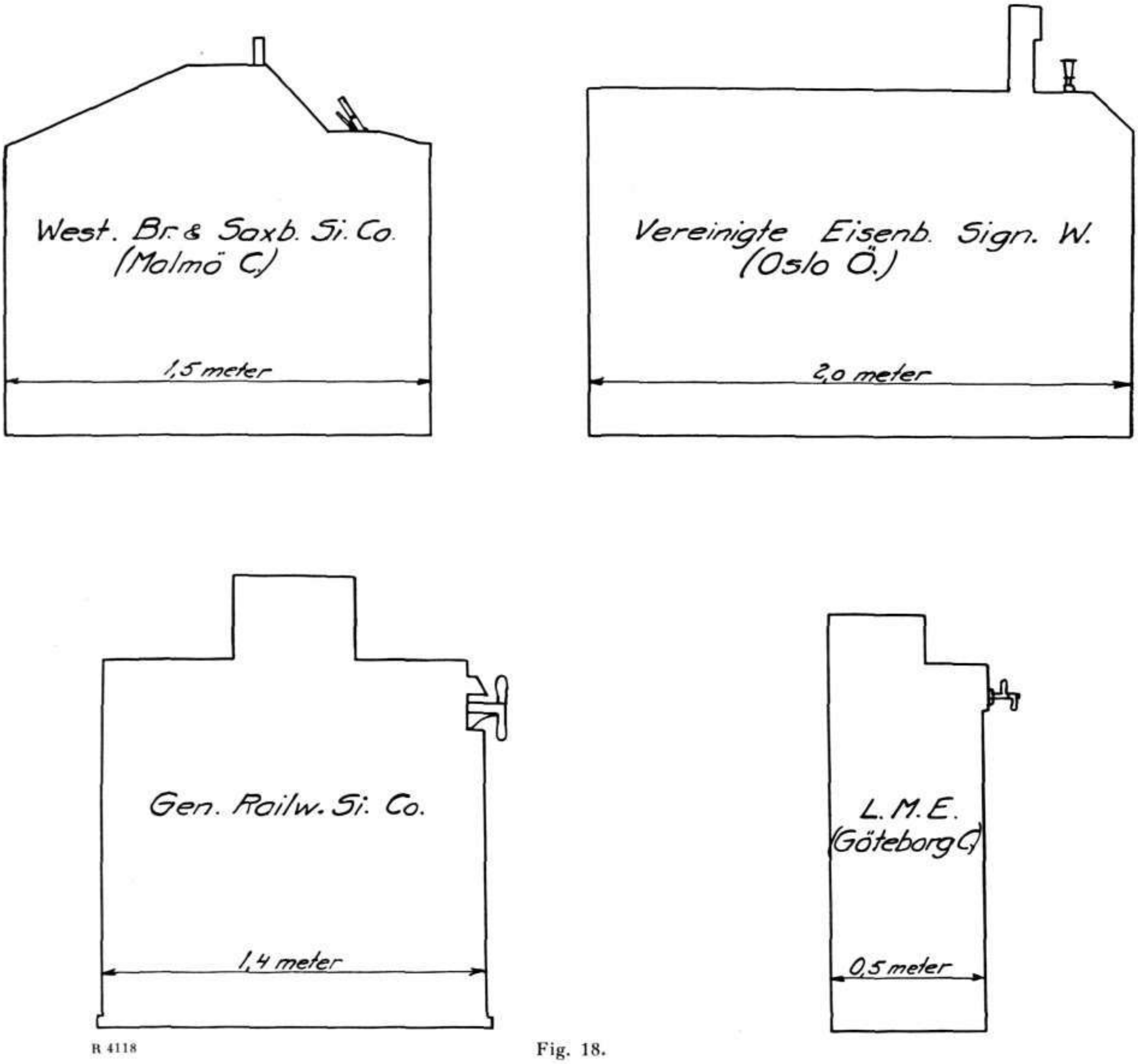


Fig. 18.

A total of 102 relays are used for controlling the dwarf signals, and 22 relays for colour light signals and platform signals. All these relays are fitted on the relay shelf on the first floor.

The illuminated track diagram.

The track diagram put up above the interlocking frame is of very great importance in the use of an installation of this type, by giving the signal men a concentrated picture of the lay-out with its signals and points.

For each track circuit there is a corresponding lamp in the diagram, this being "on" when there is any vehicle on the track circuit. Consequently when the track is empty, the lamp is "out", the result being that comparatively few track lights are seen at a time, thus making it easy to distinguish exactly those track sections that are occupied for the moment. The lamps are burnt a comparatively short time and in consequence interruptions by burnt out lamps are infrequent.

In the track diagram the indications of the signals are also repeated. The changing of the signal indications can therefore be seen simultaneously by all the staff in the signal cabin. "Caution" on a dwarf signal is repeated by a yellow light in the diagram, "proceed" by a white light. "Stop" on a dwarf signal is not repeated. The colour light signals are repeated in the plan by red light for "stop" and green for "proceed".

Other lamps in the track plan indicate when a train is ready to leave Almedal, Olskroken, or the goods yard. These lamps are placed in the plan at the outer ends of the block sections. For the Almedal Line there are two lamps, of which one is used as indication for trains to the passenger station and the other for trains to the goods station. The lamps are switched on from the signal cabins at these stations by special levers controlling annunciator relays in the Gothenburg signal cabin. There are eight of these relays, two of which are connected with Almedal, one with the goods yard and five with Olskroken.

By means of these annunciators warning is given to the Gothenburg signal cabin in due time when a train is coming. The routes in the passenger station need therefore not be cleared until it is necessary, thereby preventing movements in the station being delayed on account of the routes being set too early when trains are late.

The following lamps have finally been arranged in the track diagram at the inner end of each of the platform tracks:

one red lamp, which is automatically switched on when an incoming signal is cleared for a train from any of the three main lines to the platform track;

one lamp showing a white light when a push-button on the platform close to the track is pressed to inform the signalmen that a train is ready to start from the platform track, or that an empty train is ready to be moved from the platform track to the making-up yard; the push-button controls a time relay equipped with a contact which keeps the lamp alight for a certain time after the current to the relay is broken;

three lamps with green lights, one of which is switched on when "proceed" is displayed for a train to leave the platform track for the Almedal, B. J. and Up Lines respectively.

A small, illuminated track diagram, on which the various incoming and outgoing lines with their signals are shown, was also put up in the train office in the station building to indicate to the staff there the arrival of trains. For each incoming line there is a lamp, which is switched on when a train enters the block section. A green lamp also indicates when the incoming signal is displaying "proceed".

The power supply.

The following power consumption was estimated to be required for the installation.

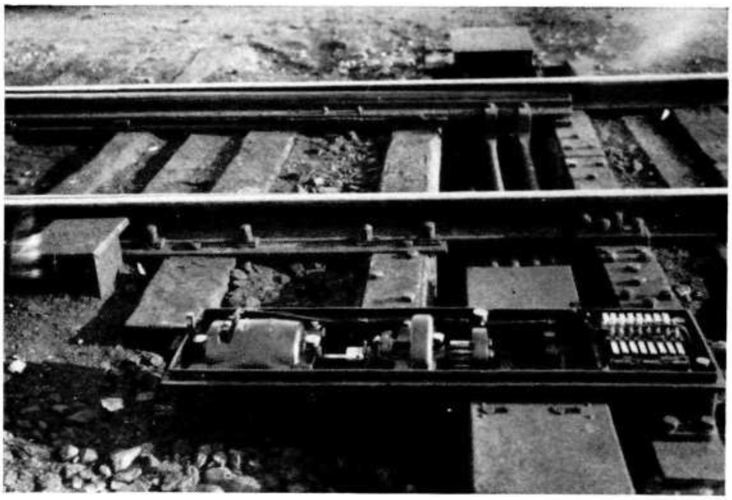


Fig. 19. Point machine.

Alternating current of 50-cycle frequency:

For lighting of the signals and the lamps in the track diagram	4.2 kw.	cos φ 1.0
For track circuits, which are provided with condensive limiting resistances..	4.8 »	» φ 0.9
For point indication relays (SS relays)	1.0 »	» φ 0.6
Total	10.0 kw.	

The above consumption is practically constant all the day round and thus corresponds to an annual consumption of about 87 000 kwh.

Direct current, 120 V:

The point motors were estimated to take a maximum of 3.6 kw. which corresponds to ten simultaneous point operations, each requiring a current of 3 amps. The total consumption depends on the actual number of point operations. With an average of a hundred operations per point motor and day, a power consumption of 360 watt per motor, and an operating time of 3 secs., about 700 kwh. per annum would be consumed.

If the A. C. supply is interrupted D. C. is used for driving a rotary converter. To obtain 10 kw A. C. of 50-cycles, about 12 kw of D. C. is required, this however being taken out only for short periods. Assuming 15 interruptions in the A. C. supply of 8 hours duration each time, a reserve D. C. supply of 1 500 kwh *per annum* would be required.

Direct current, 14 V:

About 70 watts was estimated to be required for lock magnets, control relays, telephones, etc. and had to be taken from metal rectifiers connected to the 50-cycle A. C. supply. This means an approximately constant A. C. consumption of 140 watt, i. e. about 1 200 kwh per annum.

Since the completion of the installation the power consumption for 1931 has been measured —in round figures 84 000 kwh of A. C. 50-cycles and 1 800 kwh of D. C. The power factor of the A. C. consumption has proved to be practically unity. According to the measurements the point motors are taking about 2 kwh a day, making about 800 kwh per annum, 1 000 kwh per annum thus being the power used for generating alternating current during interruptions in the normal supply.

Electric power for the installation was available from two sources, one 3-phase 50-cycle A. C. of 220 V., obtained by stepping down the high tension voltage supplied in the station from the power works of the state, and the other 2 × 120 V. D. C. from the municipal power supply. Simultaneous interruption in both sources was considered unlikely. By making provision for taking all the power required from either of these two sources, it was considered unnecessary to provide reserve power from a storage battery or a gasoline motor driven generator, a considerable saving in installation and maintenance costs thereby being made possible. In this instance the resulting reduction in floor space was also of great importance.

Considering the price of power—5 öre per kwh for A. C. and 15 öre per kwh for D. C.—the main part of the power required ought to be taken from the A. C. supply. Consequently all the power that could be used in the form of 50-cycle A. C., i. e. for signal lighting, track circuits, point indication relays, and rectifiers was taken direct from the A. C. mains.

In order to obtain A. C. from the local D. C. supply in the event of an interruption in the A. C. supply, a converter was installed in the signal cabin for converting D. C. into A. C. This converter can give 15 kwa. Should an interruption occur, both the starting of the converter and the switching over from one supply to the other have to be done by hand. An unexpected interruption must therefore cause an interruption of the work for one or two minutes, this however being of minor importance as it happens very seldom.

The point machines being designed for 120 V. D. C., the current for them could be taken direct from the local supply. To allow the power for the motors to be taken also from the A. C. supply, a metal rectifier, connected to 3 × 220 V., 50 cycles, and giving off 30 amps. D. C. at 120 V. was installed. Owing to the no-load losses in the rectifier, it proved advantageous normally to use the local D. C. supply in spite of its higher price.

The switching over from the normal supply to this rectifier is done by hand. To prevent the voltage coming back after an unexpected interruption at an unsuitable moment, for instance when a point lever is in such a position that the point motor can be affected, a "no voltage" circuit breaker is connected in the D. C. feeds, in order to break the supplies to the motors, if the voltage fails for a moment or drops to too low a value. The circuit breaker must then be restored by hand, which must not be done before taking the necessary precautions.

The 12 volts tension required for the locking magnets in the frame and for the D. C. relays is taken from a metal rectifier connected to the A. C. mains and giving a maximum of 10 amps. If this rectifier is out of order power can be taken from a rotary converter connected to 120 V. D. C. and giving 5 amps. D. C. at 14 V.

This rectifier and converter are only used for circuits inside the signal cabin, a special rectifier giving 2 amps., 12 V., being installed to feed circuits extending outside the signal cabin.

In fig. 20 the circuit diagram of the power plant is shown.

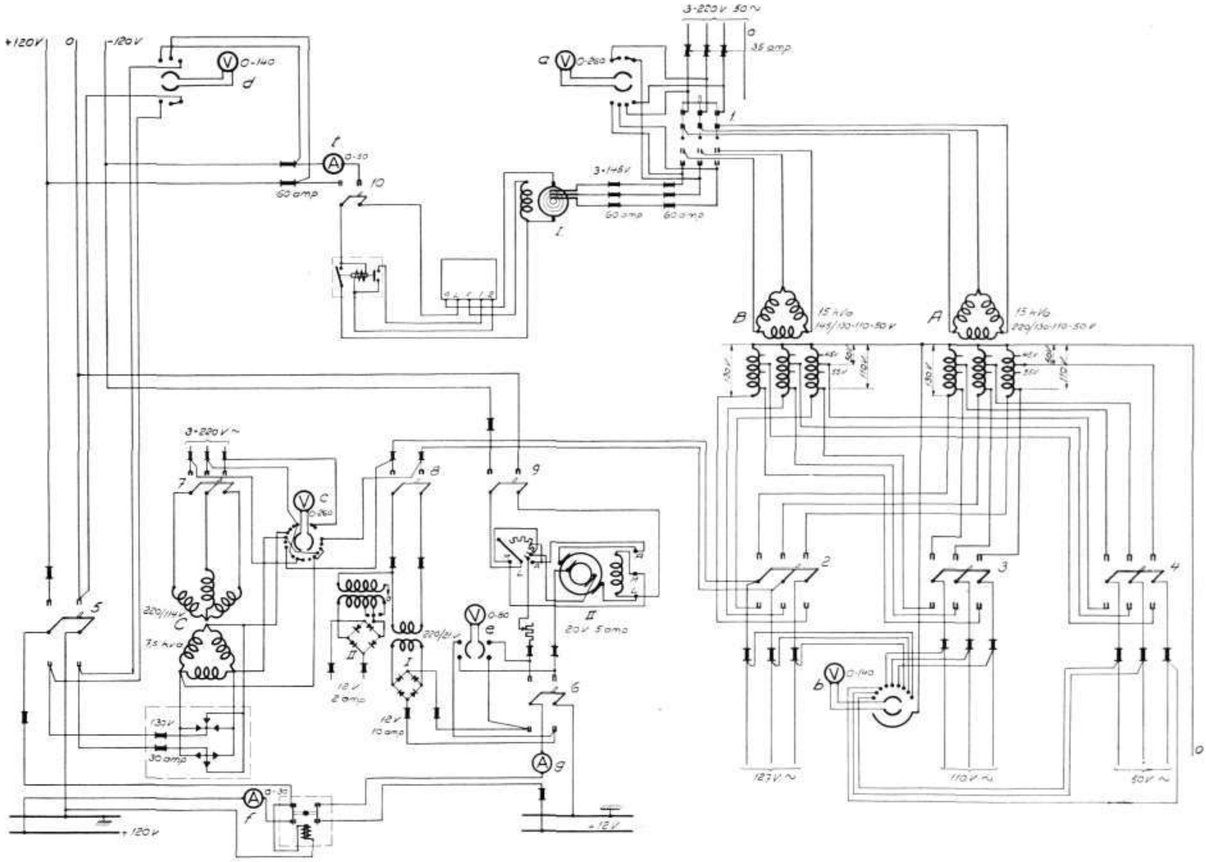


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Fig. 20.

Telephone equipment.

An important part of the installation is the telephones by which orders and information from the stationmaster and other officials are received in the signal cabin, and by which the signal men can communicate with the employees working on the ground.

A special telephone system using loud-speaking telephones with fixed microphone and telephone was installed for communications required between the signal men and the shunters when changes are to be made in the normal course of the work. A telephone is mounted in the signal cabin and connected to six telephone posts in the yard. A call can be made from any of these telephone posts to the signal cabin as well as from the cabin to any of the posts. In the latter case the call is made by means of a bell mounted at the telephone box, which summons the shunters in the yard to the telephone. The installation is energized from an accumulator charged through a metal rectifier, the same power source being used also for the bells.

A special telephone system is also arranged between the signal cabin and all the main incoming signals controlled from it. The telephones in this system are of the usual type with microtelephone. Those fitted at the signals are mounted in water-proof cast-iron boxes (so-called mine telephones), and are all connected to a common telephone in the signal cabin. This telephone system is used for communicating with the driver of the locomotive when a train has been stopped at an incoming signal. The signal men are authorized by telephone to order the train to pass the main signal at "stop" and to proceed on dwarf signals alone, which may be necessary in case of a failure in the installation or when the whole route up to the platform track for some reason cannot be cleared at the same time.

The locations of all these telephone posts are shown in fig. 5.

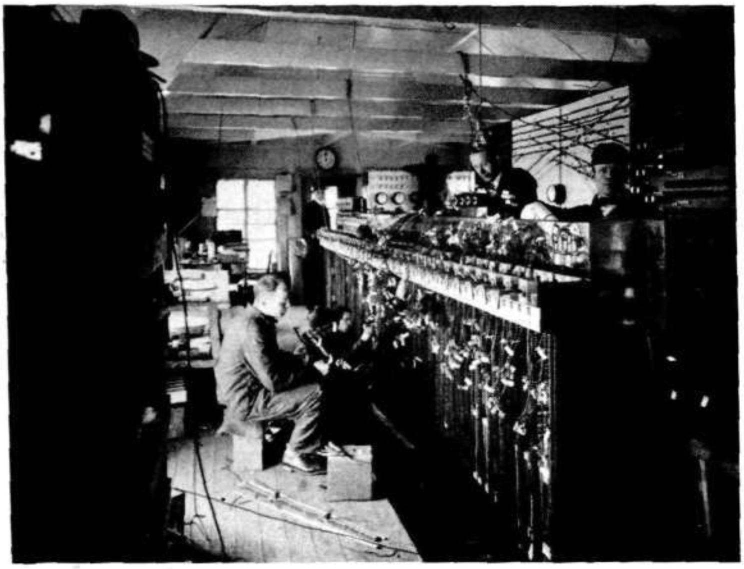

Fig. 21. Fitting of the interlocking frame, front view.

A special telephone with a line selector is also installed in the signal cabin, by which communication can be obtained with the train office in the station building, the train dispatchers office, the telephone posts on the platforms, telephones in the signal cabins at Olskroken, Almedal, and the goods yard, and finally with the local telephone system on the lines beyond Almedal and Olskroken. Incoming calls on these telephones are given by means of bells with a trembler indicator, showing the line from which the call is coming, whereupon the calling line can be connected through the selector to the cabin telephone.

Finally, an instrument connected to the automatic telephone system of the station is also installed in the cabin. This provides communication with all the offices of the Gothenburg yards, the train order telephone systems of the different railways as well as the public telephone system.

The construction and placing in service of the plant.

All designing work and purchase of material were carried out at the office of the Signal Department of the State Railway at Stockholm. The installation work was under the general control of the engineer in charge of the whole rebuilding of the railway station and was supervised by an engineer appointed from the staff of the Signal Department. The inspection of the wiring and other details and the technical arrangements in connexion with the placing of the plant in service were made by this engineer, who also assisted in instructing the traffic and locomotive staffs in the use and meaning of the signals.

The installation work began on Oct. 6th, 1929. The track lay-out was then far from completed, which made the work considerably more difficult. The signal cabin, on the other hand, was at that time practically finished. The greater part of the material for the plant was furnished on the spot, the remainder being on order for successive deliveries at the dates when, according to the working scheme, they would be required.

According to this scheme the outside work—i. e. cable work and works on points and tracks—was to be completed first, so as to be ready if possible before the beginning of winter. Work inside the signal cabin, being independent of the weather, was to be done last, which was also most convenient on account of the interlocking frame and the track diagram not being expected to be ready for delivery until the end of the year.

The installation was favoured by a comparatively mild winter, and the plant was ready for use on the appointed date, May 2nd, 1930. At that date only the traffic previously dealt with by the Gothenburg S. J. entered the station. It was not until May 15th that the traffic was taken over from the Gothenburg B. J. station, which then ceased to be a passenger station. At the same time a new time-table, to meet the altered conditions, came into force. This meant that the traffic in the new passenger station was suddenly increased by 150 per cent.

After the station was taken into use, it was found that the sidings for storing and marshalling of empty trains was not quite sufficient for the demands of the traffic, and some new tracks and points had therefore to be laid out immediately. Track M and track group O (see fig. 5), as well as the scissors cross-over at points 1-3-5-7, and also points 4a and b, and 24, were thus added when the installation was already in service. This naturally involved some alterations and extensions of the signal installation also. The frame with electric register chosen for this plant now came in very well as the necessary alterations of the frame could easily be done without interfering with the traffic.

Fig. 22. Fitting of the interlocking frame and illuminated track plan, back view.

Including these alterations and other adjustments and final touches, which were not completed until June 1930, the whole installation had required the following labour:—

1 engineer from the Signal Department, in all	200 working days
2 fitters from the L. M. E. Signal A.-B., in all	300 » »
3 signal maintainers from the State Railway, in all	780 » »
8 skilled workmen (blacksmiths etc.)	1980 » »
helpers in varying numbers per day, max. 40, in all	3240 » »
Total	6500 working days.

In the installation work electrically operated tools were largely used for drilling holes in point tongues and rails for the fitting of point machines and insulating joints. Rails and tie plates were cut with acetylene burners. Rail bonds and leads were electrically welded to the rails within the station boundaries, while on the line, where electric power was not easily available for welding, they were soldered with the aid of acetylene flames.

Fig. 23. Welding of rail bond.

The rolling out of the cables was as far as possible done from trucks moved by shunt engines. The wiring and cable work, both in the signal cabin and on the ground, was as far as possible done by piece-work, i. e. the work was divided among gangs, each doing one particular detail of the work. Piece-work rates could thus be largely applied, and the training of labourers for the various tasks was facilitated.

The cost of the plant appears from the table below, which gives the actual expenditure in round figures, and includes all costs except designing and other work carried out at the Signal Department's office at Stockholm:—

Signal cabin	Kr. 42 000
Interlocking frame, track diagram, and relays	» 117 000
Point machines, with connecting rods and plates	» 75 000
Signals, with transformers, foundations, masts and suspending devices	» 27 000
Cables, with boxes, compound, and cover	» 60 500
Power plant	» 11 500
Telephones, with accessories	» 6 500
Push-buttons and relays for controlling starting indicators from the platforms	» 2 000
	Kr. 341 500

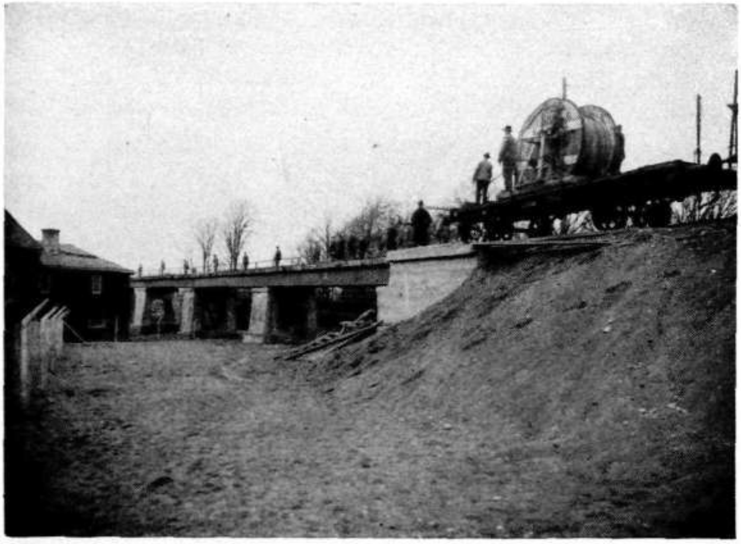

Fig. 24. Cable laying.

	Kr.	341 500
Track circuit materials, including rail bonds, leads, insulating joints, track transformers, condensers, relay transformers, connecting boxes, housings for transformers, wood conduits for leads between the rails, rail bolts, spring washers, gas, electrodes and other materials for welding and soldering bonds and leads	»	25 000
Duplicate apparatus for reserve	»	2 500
Labour	»	93 000
Total	Kr.	462 000

Operating and maintenance.

Between 1 a. m. and 6 a. m. only one man is on duty in the signal cabin for operating the interlocking frame, and at other times of the day two men. Between 7 a. m. and 10 p. m. a foreman is also stationed in the signal cabin for the special purpose of supervising and directing the work, receiving incoming orders and information regarding traffic movements from the stationmaster or from adjoining stations, and forwarding information to the shunters and train men. The total number of working hours in the signal cabin is thus 58 per day, of which 15 hours for the foreman and 43 hours for the signalmen. With a working day of 7 hours and a half for each man, this necessitates a signal cabin staff of 7 to 8 men.

For the maintenance of the installation one chief maintainer, 2 maintainers and 2 signal helpers are employed. The same men also are charged with the maintenance of other interlocking plants within a certain area round Gothenburg. The chief maintainer also does work on other plants within the second district of the State Railway, having its headquarters at Gothenburg. The supervision of the maintenance rests on the District Signal Engineer.

To prevent interruptions of the traffic should a failure occur, the service is arranged so that always at least one signal maintainer or helper is on duty near the signal cabin to be rapidly called for when needed. Attendance has so far also been arranged at night on account of the important trains then arriving or departing. Attendance is also arranged on Sundays, the number of trains being then practically the same as on weekdays. A workshop for overhauling old signal material having been located near the cabin, the men on duty can be employed in productive work even though no maintenance work would be needed on the installation itself.

The technical supervision includes on the one hand a general inspection of the plant to be done daily, on the other hand tests to be made from

Fig. 25. Testing a cable distribution box.

time to time to make sure that all important safety devices are functioning properly. According to the general rules, a more complete inspection is to be made at least 4 times a year, at regular intervals.

The following tests are usually made. The points are tested by trying to lay them over when an object 5 mm thick is applied between the stock rail and the tongue. The point motors are also checked to see that their field windings are properly short-circuited by contacts on the respective point levers, when these are in their extreme positions. Similarly, the shunting of the indicating windings of the point indication relays, when the points are in an intermediate position, is duly checked. Tests are also made to see that there is no earthing of circuits which ought to be insulated from earth. The shunt values of the track circuits are measured, and the tracks examined to see that all parts are properly connected to the track relay. In the regular inspections, special attention is finally given to the interlocking frame itself, this being gone through to inspect the proper operation of locking devices, magnets, and contacts.

In spite of careful inspection, it may be unavoidable in an installation of this size that failures sometimes occur on account of defects in one or other of the many details of which the plant is composed, this being the case particularly during the early days of its use before all the parts—many of which could not be finally tested until the plant was placed in service—are properly adjusted.

To obtain a full knowledge of failures occuring, a record has since the installation was placed in service been kept of all defects, including even such as have been of little or no importance to the work and have been immediately put right. From this record the Signal Engineer has month by month made up failure statistics, from which a survey of the number and causes of the failures can be obtained. By studying the individual causes it has been possible gradually to increase the reliability of the installation and to reduce the number of failures either by improving certain details or by directing the attention of the maintainers to devices requiring special care.

The point machines were of a new type, which had not been tested under such trying conditions. It was found necessary to exchange the contact blocks of the circuit controllers of the machines, as the contacts were not firmly enough fixed in the insulating material. Further, the design of the breaking device of the point motor was altered, and the friction clutches were gradually adjusted to increase the pulling power. In the locking frame the fixing of certain movable parts of the lock magnets was amended, as they had shown a tendency to loosen after frequent operations. A thorough adjustment was also made of the attachment of the wires to the binding posts of the contact springs of the frame, after loose contact had been found in some cases on account of shrinking of the insulating material of the contact blocks. By these measures about 50 per cent, of the failures occuring during the first period of the plant's being in service could be prevented for the future.

One category of disturbances which it is not possible completely to eliminate are those caused by purely external obstacles to the operation of the points, such as snow or ice in the points, gravel or stone from the ballast occasionally getting in between the tongues and stick rails, or displacements in the track which may prevent the points from being completely laid over. In 1931 the total number of such cases was 18, which, however, is a very small fraction of the one or two million annual point operations.

Failures have been reported in the locking devices of locally operated points in 4 cases, due to the formation of ice on the contact surfaces. The same kind of failure has not occured in the point motor, as these are provided with a higher contact pressure.

Only in 4 cases during 1931 has it happened, owing to contact failures in points and relays, that "proceed" indication has not appeared when it might.

A strikingly small number of failures—in all 8 during 1931—have been traced to the track circuits, and were caused by wear of the fibre packings in insulating rail joints (6 cases), metallic contact between the rods in a pair of points (1 case), and defective contact in a terminal screw of a cable distributing box (1 case). This small number proves the high degree of reliability obtainable by means of track circuits even in a comparatively complicated track lay-out with rather heavy traffic.

Disturbances by small failures of various kinds in the interlocking frame from other causes than those mentioned above, which could be eliminated in future by certain measures, occurred in 7 cases during the year, in addition to which there were 6 cases caused by too high resistance in the contacts of various relays in the signal cabin.

15 cases of interruption of the A. C. supply, when the installation had to be switched over to the converter connected to the D. C. supply, have also been resorted as failures.

Finally, there is a special category of failures caused by burnt out signal lamps. Periodical changes of lamps after a certain period of use have not been arranged, but the changing of lamps has been made as they have become useless, through either the filament breaking or the light being dimmed by a dark deposit in the bulbs. Records have been kept of replacements made at each light, in order to find out the durability of the lamps, and also to discover any abnormal consumption of lamps possibly caused by too high voltage or by defective lamps. The total number of lamp replacements was only two in colour light signals, where 12 V., 24 W, lamps are used, and 20 in the dwarf signals, where 55 V., 20 W, lamps are in use. The number of lamp replacements in the track diagram was 25 during the year.

Economic results.

A direct estimate of the saving in operating costs by this plant is difficult, as it was installed in connexion with an extension of the station by more than 100 per cent. as far as the number of platform tracks, points, and incoming or outgoing lines are concerned, and was from the very first organized for taking over a traffic exceeding in volume the previous one by about 150 per cent. There is therefore no material available for a direct comparison showing what savings of staff have been possible by centralizing the signalling of the station and the adjoining lines into one single cabin at Gothenburg C.

Some assistance in estimating this saving may be obtained by a comparison with Malmö, where an installation of the same type and approximately the same size and with similar operating conditions, was placed in service in the year 1925. The new installation at Malmö, which was the first of its kind on the State Railway, was built without extensions being made of the station or alterations as to the amount of traffic. A direct comparison was therefore possible between the number of staff required before and after the installation was placed in service. The former installation at Malmö was a mechanical one, divided between two signal cabins in the station and 2 manual block posts on the incoming lines, one having a junction for goods trains at about the same distance from the main station as the outlying points on the Almedal Line. Experiences from Malmö indicate that the staff could be reduced by 22 men on account of centralization of the signalling.

By courtesy of the Station Master an attempt has been made to estimate what increase of staff would have been required if a mechanical system instead of an electric one had been installed at Gothenburg C. The result indicates that, beyond the present staff, the following additional personel would have been required:

for the outlying points on the Almedal Line	3 men
for operation of route releasing instruments in the station master's office	2 »
for the main cabin	2 »
for an additional signal cabin	5 »
locomotive pilots	2 »
signalmen on the ground	2 »
Total increase of staff for Gothenburg C	16 men

In addition more men would have been required at neighbouring stations also, Olskroken in particular, where the work would increase considerably if the line-blocking of the 5 lines to Gothenburg C had to be operated manually without the aid of track circuits and automatic signals. If this increase of staff is estimated at 2 men, the estimated total saving in personel compared with a mechanical plant would be 18 men.

To use this station without interlocking and with all the points operated on the ground must be considered as an alternative beyond practical possibility. Even with a further heavy increase of the number of staff it would meet with insuperable difficulties in such a case to be able to handle the trains in the time available.

The initial cost of a mechanical plant would probably have been less than the cost of the plant now in service, but the interlocking of the 60 points and about 30 signals would certainly have cost at least 300 000 kr., even if a mechanical system had been used. In view of the technical limitations of a mechanical system, however, the use of such a system would necessarily have meant a considerable reduction of the number of available routes for the trains, as well as of the efficiency of the installation from the safety point of view.

A plant with electrically operated points and signals but otherwise made on the same principles as a mechanical plant, without track circuits and shunting signals, i. e. on the system used in several installations of an earlier date on the State Railway, might have been installed for approximately the cost estimated above for a plain mechanical installation. Owing to the greater ease of operating an electric interlocking frame, the signal cabin staff might then be reduced by about 4 men, so that the increase of staff over the present might be estimated at 14 men, instead of 18 with a plain mechanical system.

It should be observed, however, that it is an open question whether the present number of platform tracks and track facilities for shunting empty trains to and from the making-up yard would suffice, even with the additional personel estimated above, should a signalling system without track circuits and shunt signals be used, as the operation of points for shunting and train movements could not be performed as quickly as it is now.

It is mentioned in the introduction to this paper that the choice of the signalling system from the first affected the design of the station in making it possible to reduce the number of platform tracks, a reduction which would not have been advisable with a signal installation of less efficiency. An estimate of cost carried out by direction of the Railway Management indicated that an extension of the number of platform tracks from the present 10—including an eleventh track for outgoing trains—to 12 complete platform tracks would mean a capital outlay of 525 000 kr., i.e. an amount considerably exceeding the total cost of the present signal installation. In a letter from the Railway Management to the Government of Sept. 27th, 1930, on the subject of granting money for new improvements of various kinds on the railway, a report was given on the effect of the newly finished rebuilding of the Gothenburg station. The Railway Management stated in this report that the traffic taken over by the new station had proved to be considerably greater than expected when the station was designed some years ago. It might therefore become necessary to extend the station by two additional platform tracks in order to safeguard the regular handling of the traffic. The Management was however not convinced that an extension would prove absolutely essential, and wanted therefore to postpone the question of granting money for this purpose—to be able to make further observations before a final decision could be made.

Since then two years have passed, during which the number of trains, as indicated by the the diagrams given in fig. 4, has been further increased without causing any difficulties for the proper handling of the traffic. The Railway Management has consequently in subsequent propositions definitely abandoned the project of extending the platform tracks.

Without exaggeration it might thus be said that the additional sum of 160 000 kr.—being the difference between the cost of the present plant and a simplified one—spent on signalling facilities at Gothenburg C, has resulted in not only a saving in personel of no less than 14 or 18 men, but also in putting off a direct capital outlay of about 525 000 kr., as not needed in the reasonably near future.

The collection of the information given in this paper has been greatly facilitated by the courtesy of Teodor Lundberg and John Olofsson, of whom the former has been in charge of the installation work, and the latter of the designing work. The author has further taken the liberty of using the occupation diagrams made out by the Yard Construction Department of the State Railway, as well as the information supplied by the District Signal Engineer, regarding the organization of the maintenance, and is finally indebted to the Chief Station Master at Gothenburg, E. Ericsson, for the valuable information regarding the operation of the plant.