PAPER No. 387

Immunisation of Signalling Equipment in Connection with Electrification of Lahore-Khanewal Section of Pakistan Western Railway

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1. Introduction

1.1. Lahore-Khanewal Section of Pakistan Western Railway is being electrified with 25000 v 50 c/s A.C. This project has now reached the execution stage and trial runs between Lahore and Raiwind will commence from June, 1968.

1.2. Mr. S. H. Nawab OSD/Electric Traction (now C.E.E./R.E.), contributed a paper on electrification of Pakistan Western Railway during the last session of West Pakistan Engineering Congress. He discussed at length the reason for deciding on 25000 v 50 c/s A. C. traction and selecting Lahore-Khanewal as the section for electrification. No effort was made to comment on the repercussions of electrification on the existing installation, such as signalling circuits, Distribution Lines, Telegraph & Telephone & Control Lines etc. It is proposed to discuss in this paper effects of electrification on signalling circuits and proposed modifications and additions to meet with the situation. In order to make the paper a little more comprehensive and to provide a background to the proposed additions and alterations, it is considered appropriate to describe briefly the Railway Signalling on the section and detailed working of different components of Signalling System.

2. Signalling on Lahore-Khanewal Section

2.1. Lahore-Khanewal Section is 182 miles in length and situated on main line, Karachi-Lalamusa Section. This section serves the most fertile and industrialised area of former Punjab. In order to meet with heavy traffic converging at Raiwind, the section Raiwind-Lahore, a length of 25 miles is double line. Raiwind to Khanewal is all single line. There are in all 35 stations, 6 on double lines and 29 on single line. In order to meet with the increased traffic larger block sections are being cut and more stations are being provided.

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In all seven new stations are proposed to be opened during current five-year plan on Raiwind-Khanewal section in order to increase the sectional capacity.

2.2. The signalling on this section is of electro-mechanical type. The points and signals are operated mechanically but an electrical control exists so much so that signals cannot be taken off unless the Station Master authorises the lowering of signals by allowing the electric feed to the cabins which ultimately goes to the signals. The signals and points are operated from cabins located at either end of the yards. The interlocking provided in these cabins ensures that no signal can be taken off unless the line on which the train is to be received is set and locked. Once a signal has been taken off it is not possible to take off any other signal which interferes with the path set for the train. In case the signal is to be put back to danger for some reason or the other, it can be done by putting the slot back from station or cabin.

2.3. The authority to proceed from the station to the next is given and obtained on Block instrument specially designed for the purpose. On double line these instruments are known as Tyer's Double Line Block instruments and and on single line Siemens Tokenless Block instruments. These instruments ensure that there is only one train in the section and unless the instrument is brought to normal after clearing the section, fresh line clear cannot be obtained or given. As a further safeguard, the Advance Starter Signal controlling the entry into the section, goes back to danger automatically as soon as the train passes; the signal cannot be cleared again unless fresh line clear is obtained. Siemens type Tokenless Block instruments have been installed about 2 years back, in place of Neale's Ball token instruments. The new instruments have contributed appreciably in increasing the sectional capacity.

2.4. As a further step to ensure safety Track Circuits have been provided at Lahore, and all stations on Raiwind-Khanewal section. This ensures that reception signals cannot be lowered if line is occupied by some load. This subject has been discussed at length in para 4.

3. Immunisation : Why required :

3.1. The first question that comes to mind is as to what is immunisation and why it is required. 25000 volts AC is proposed to be utilised for electric traction. One rail of the track is to be used as the return for traction current. In the vicinity of 25000 AC traction voltage the overhead wires are subjected to electrostatic and electro-magnetic induced voltage. In case of overhead conductor running within 35 feet of 25 k.v. line, voltage induced in it due to electro-static induction might be as high as 1000 volts. This induced voltage can falsely energise the different relays used in signal circuits and may create conditions which are unsafe for train operation. In order to reduce this electrostatic induction, it is essential to transfer all signal circuits from overhead to underground.

3.2. The underground wires are still susceptible to electro-magnetic induction which is directly proportional to the current in the catenary. This induced voltage has been estimated to be in the neighbourhood of 50 volts per mile of parallelism. The length of parallelism must be kept within two milesin order to keep the electromagnetic induced voltage to about 100 volts. As the length of the cable from outer to outer signal at a wayside station on Lahore-Khanewal section is about 1½ miles; the induced voltage will be about 75 volts.

Signalling equipment which generally operates on low voltage has to be immunised in order to avoid false energisation of equipment such as relays, reversers, indicators, bells, arm and light repeaters, signal machines, block instruments etc. etc. Proposed modifications and additions to different items are discussed in greater detail in the following paras.

4. Track Circuits

4.1. One of the most important items of signalling to be immunised in connection with electric traction is the existing track circuits. Before explaining the details of steps being taken to immunise the track circuits it will be worthwhile to describe in some detail the functions and the reasons for providing them. According to the Association of American Rail Roads (Signal section) a track circuit is defined as an electrical circuit of which the rails form a part. A simple track circuit consists of an insulated track with power feed at one end and a relay at the other end. This relay known as track relay remains in energised position under normal conditions but drop away as soon as any vehicle comes over the insulated portion of the track circuit. A sketch showing a simple track circuit and the control of a signal through the track relay is shown in figure 1. It will be seen from the diagram that the track relay normally remains picked up and signal can be cleared to 'off' position if required but as soon as the track circuited portion is occupied, the electric supply gets an easier path through the axles of a train and results in dropping of the track relay. As soon as track relay drops, the signal which may be a semaphore or a colour light signal goes to danger immediately. Thus it will be seen that at stations where track circuits are provided, it will not be possible to take off a signal in case the line on which train is to be received is not clear. This basic safety aspect of track circuits has made track circuits as one of the most important inventions on the Railways since the steam locomotive. The track circuit was invented in 1872 and after the passage of nearly a century, the track circuit is still essentially the same as was invented by Dr. Robinson of U.S.A. and is extensively used for all modern signalling purposes.

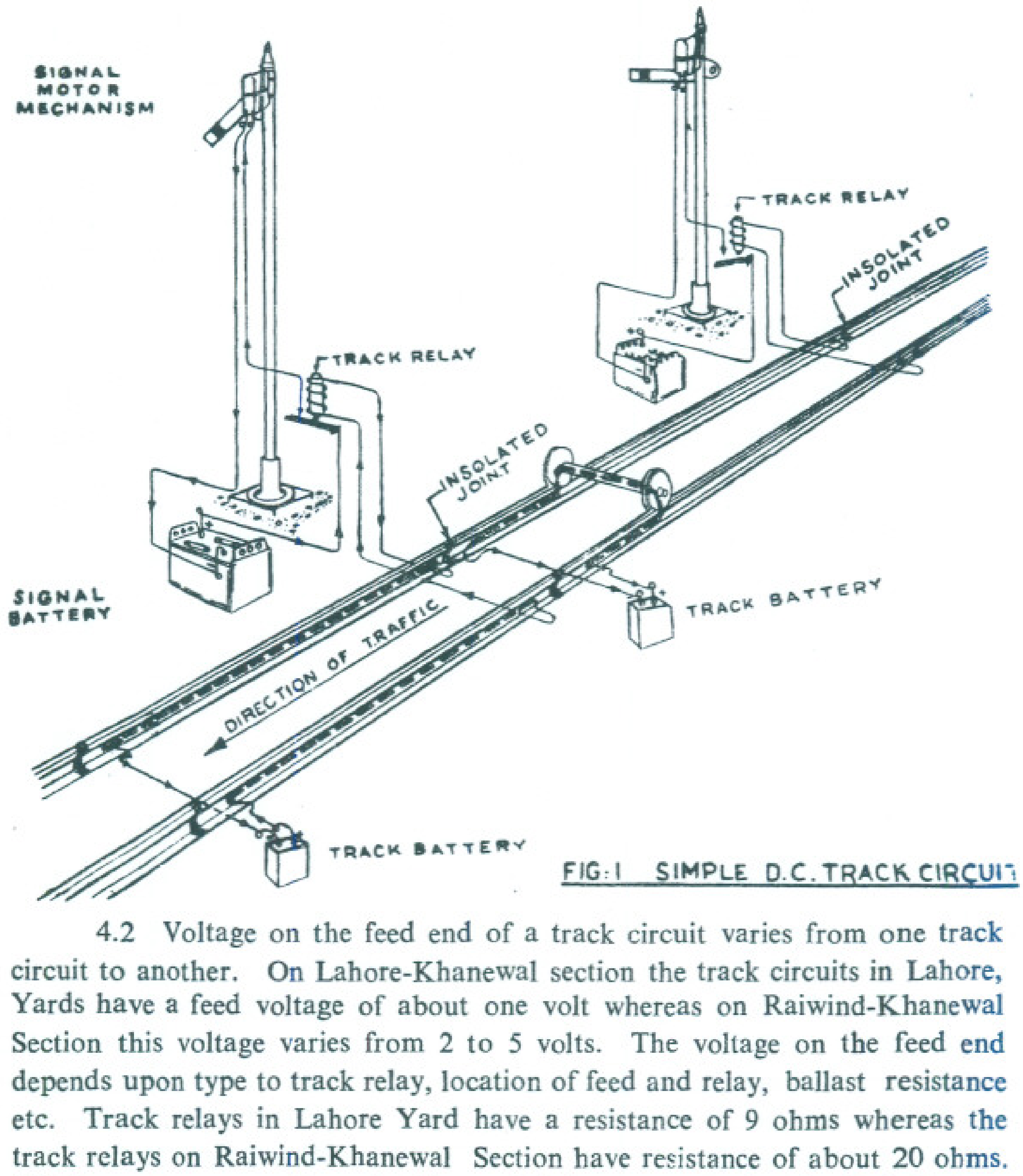

FIG: I SIMPLE D.C. TRACK CIRCUIT

4.2 Voltage on the feed end of a track circuit varies from one track circuit to another. On Lahore-Khanewal section the track circuits in Lahore, Yards have a feed voltage of about one volt whereas on Raiwind-Khanewal Section this voltage varies from 2 to 5 volts. The voltage on the feed end depends upon type to track relay, location of feed and relay, ballast resistance etc. Track relays in Lahore Yard have a resistance of 9 ohms whereas the track relays on Raiwind-Khanewal Section have resistance of about 20 ohms. All the passenger and goods lines at Lahore are track circuited, but on Raiwind and Khanewal stations only passenger running lines have been track circuited. On all wayside stations, on Raiwind-Khanewal section only the main line has been track circuited. The system of feeding the track circuits is different in Lahore and at stations on Raiwind-Khanewal Section. At Lahore 110 volts A.C. is transmitted to the location boxes where it is transformed/rectified to 2.5 volts D. C. and through a resister in series about one volt is fed into the track. At the other end a track relay is connected and housed in a location box near the track. The condition of the track relay is repeated in the Relay Room near Station Master's office with a 1000 ohms track repeating relay. Track Circuit layout at Lahore is shown in figure 2. On Raiwind-Khanewal Section a battery of 14 volts is located to a Battery Room near the Station Master's office and through a variable resistance, feed is transmitted through a cable into the track. Track relay is also located in the Relay Room near Station Master's office. This system is known as control system in which the feed as well as relays are housed near the Station Master's office which facilitates testing and maintenance but this system has its own drawbacks. This needs lengthy discussion and is beyond the scope of this paper. The track relay in the Station Master's office pick up at minimum voltage of .85 and can safely work up to a maximum of about 5 volts. The voltage to the feed end is adjusted in such a way that the voltage at the relay end remains at about 2 to 3 volts during dry weather. Voltage is adjusted according to the weather conditions. In case of wet weather and drop of ballast resistance the voltage is increased to such an extent that relays remain in energised position. These two arrangements are shown in figures 2 and 3 below :—

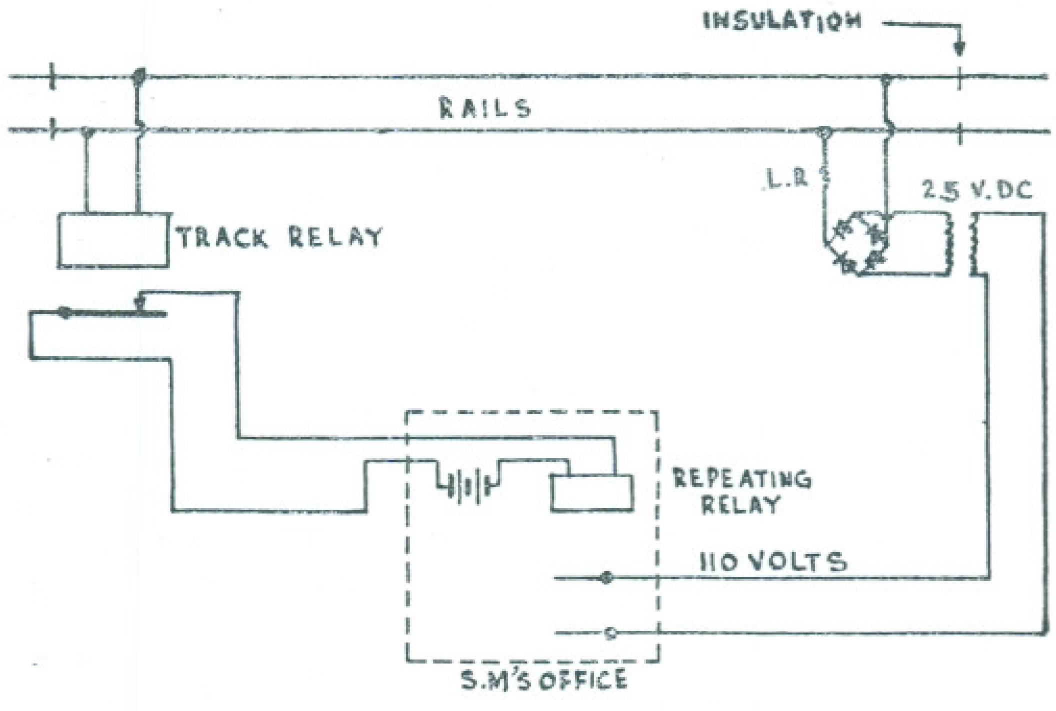

FIG: 2 TRACK CIRCUIT LAYOUT LAHORE YARD

In certain cases on Raiwind-Khanewal Section, track relays have been provided in location boxes near the relay end and repeating relays working on 60 volts are provided in the Relay Room. The reasons for shifting of these relays to location cases is poor ballast resistance and high resistance of cable from relay end to the relay room.

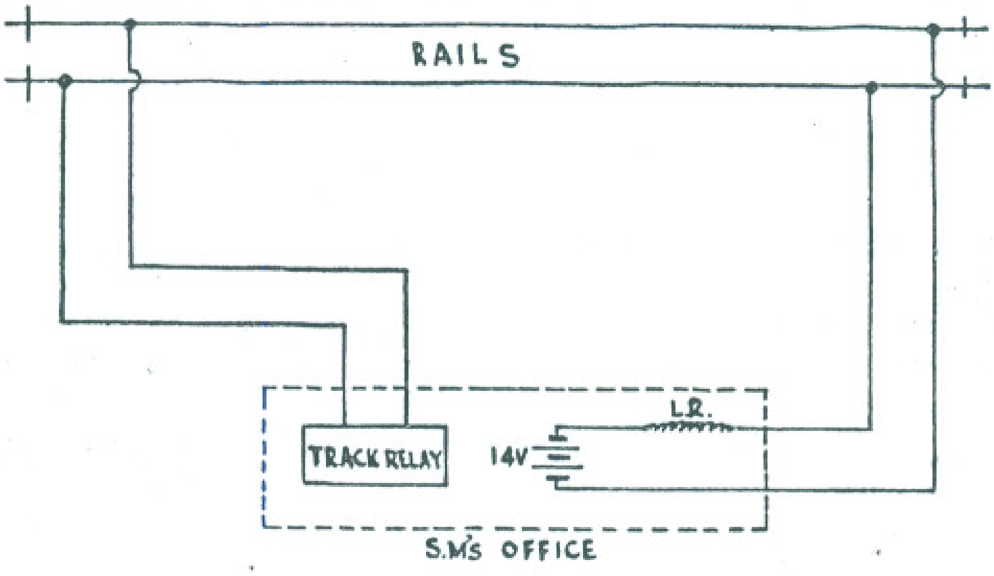

FIG:3 TRACK CIRCUIT LAYOUT RND-KWL SECTION

4.3. Although the details about track circuits given above are not exhaustive but with this background we can proceed with the details of modifications proposed to be carried out to immunise the track circuits. At present double rail series track circuits have been provided. A double rail series track is one in which the circuit starting from positive of the battery up to a negative of the battery is in series with the result that any breakage in the rail, cable, wire on any other component de-energises the track relay and the signal goes to danger. With the introduction of electrification one rail has to be utilised for traction return current. Thus the track circuit has to be provided in such a way that negative of track circuit and return for traction current is taken on one rail and positive of track circuit on the other rail. No insulation is provided on the negative rail between two track circuits. This is known as a single rail track circuit. Difference between single and double rail track circuits is shown in diagrams No. 4 and 5.

The entire arrangement of track circuit, its insulation etc., will be arranged in such a way that one rail is left for the traction return current. In case the positive of track circuit has to shift from one rail to another, the return rail shall also have to be shifted to the other rail and a cross bond has to be

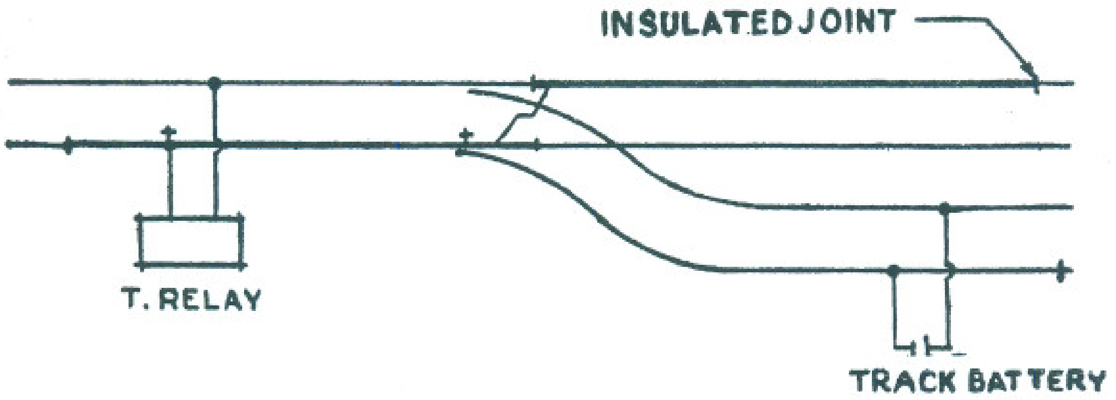

FIG: 4 SINGLE RAIL TRACK CIRCUIT

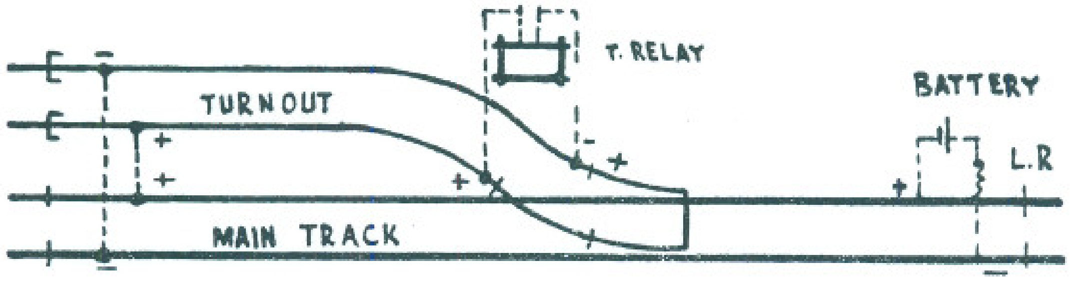

FIG:5 SERIES CONNECTION TURNOUT

provided. This cross bond should be very robust and thick enough to carry the load of the return current and the maintenance must be of the highest order as the breakage of this bond can result in a very high current on the joint and may result in melting of the rail at the joint. Cross bond is shown in diagram No. 6.

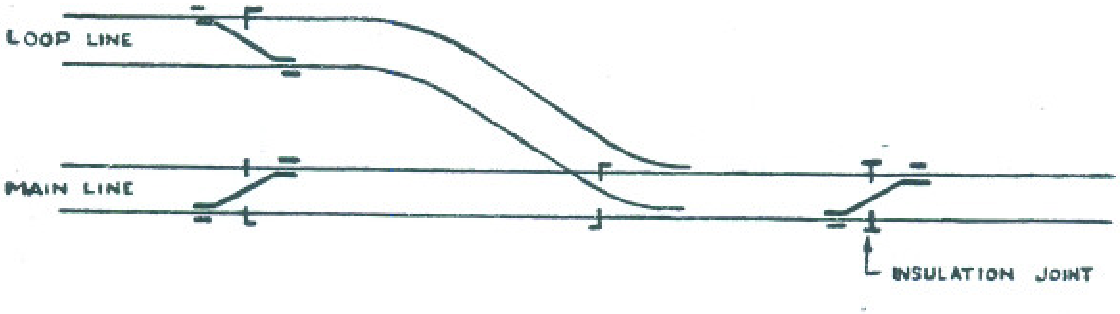

FIG: 6 CROSS JUMPER ON A TURN OUT

4.4. It is proposed to dispense with the system of central battery feed and to introduce the system now in use in Lahore Yard *viz.*, 110 volts AC up to location boxes and rectified voltage for feeding the track circuits. The central battery system is not suitable as the earth fault on two track circuits may lead to a very high current passing into the battery and may result in complete damage of battery and other equipment. The revised arrangements of a track circuit showing its feed and relay ends is given in figure 7 below.

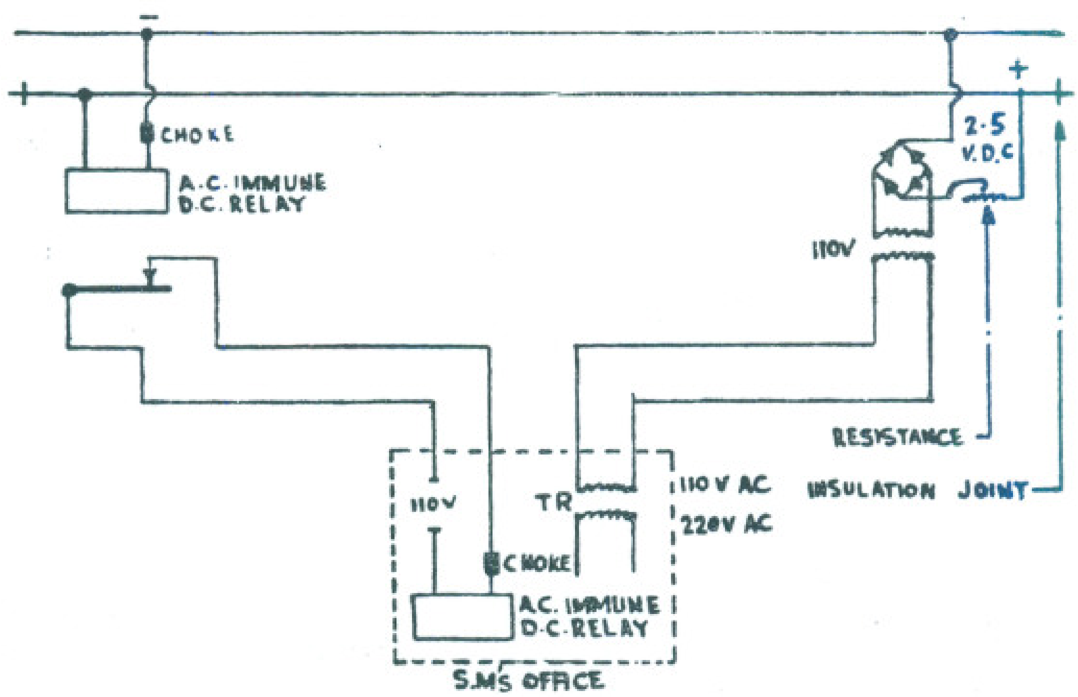

FIG. 7 MODIFIED TRACK CIRCUIT

The track relays to be provided shall be AC immune DC relays. Copper slugs are provided over the cores near the pole pieces and a magnetic shunt fitted between the cores above the copper slugs. When D.C. is applied to the relay windings, the armature is attracted in the usual way, although some of the flux is shunted by the magnetic shunt. When A.C. is applied, the flux it produces tends to short circuit the air gap via the magnetic shunt, since the copper slugs tend to prevent the flux from establishing itself across the air gap. The relay cannot be picked up by A.C. induced voltage. A sketch showing such a relay is in figure 8.

In order to further ensure that the relay does not pick up with induced voltages, a choke is provided in series with the track relay. The combination of an AC immune D.C. relay and a choke in series ensures that the relay does not pick up with induced voltage up to 1000, and choke shall also be provided to avoid false energisation of these relays. As the safety of the entire signalling system depends upon proper functioning of track relays, it is absolutely necessary that the track relay and its repeating relays do not operate falsely and no

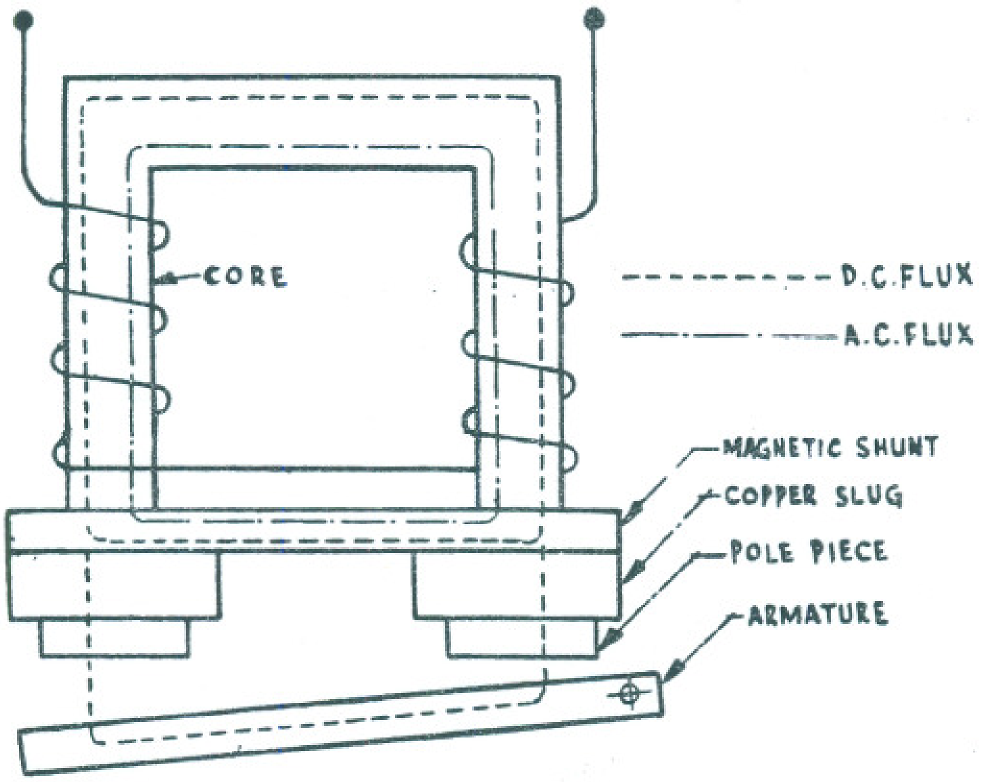

FIG.8 D. C. RELAY. A.C. IMMUNE

outside voltage whether induced or due to any fault affect the track relays at all.

5. Slot Circuits

5.1. The second item which is to be immunised from induced voltages is the slot circuits for controlling different reception and departure signals. On all the stations from Lahore to Khanewal, the signals are electro-mechanically controlled and cannot be taken off unless the Station Master pulls a slide and authorises the Cabinman to take off a particular signal. Layout of a typical single line station with signals and position of cabins is shown in figure 9 on next page.

Home signals, warner signals and advance starter signals can only be lowered when the Station Master pulls a particular slide. Outer signal does not need a slot but can be lowered when one of the Home Signals has been lowered. A typical slot circuit diagram for main line home signal is given in figure 10 given on next page.

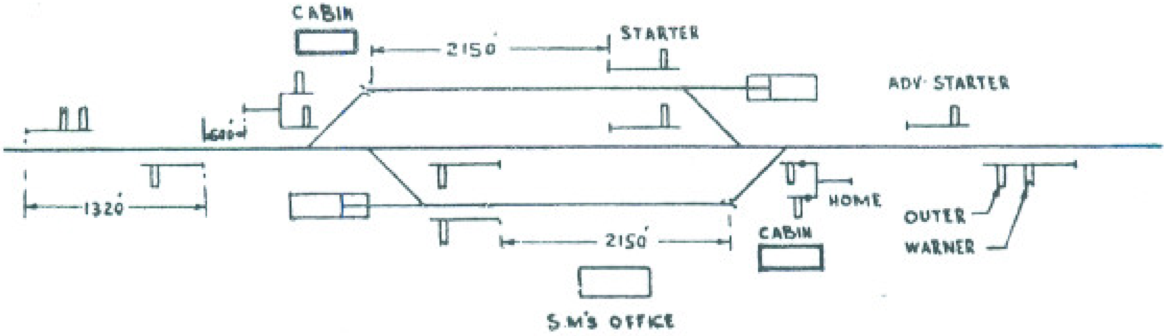

Fig. 9. Typical Yard Layout on Single Line Station

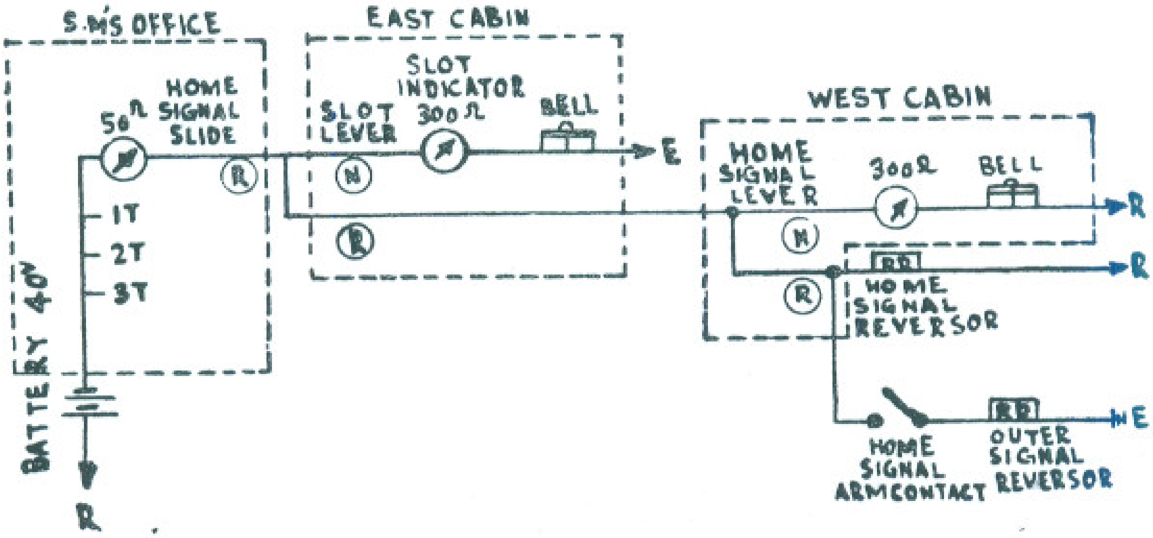

FIG 10 SLOT CIRCUIT FOR MAIN HOME SIGNAL

As soon as the Station Master on duty pulls the main line home signal slide, current flows to the cabin on the opposite side of the home signal to be taken off. Thus Cabinman gets an indication and a bell about the signal to be lowered. He checks his portion of the line and after satisfying that the line is clear, transmits the slot to the other cabin by pulling the slot lever. By pulling the slot lever, the current goes to the other cabin where a bell rings and the indicator gives the No. of the signal which is to be taken off. The Cabinman on duty after setting and locking the line pulls the home signal lever. As soon as the lever is pulled by about 30 degree the current goes to a electric coil fixed with the arm of the signal known as a reverser. This electro-magnet is energised and when Cabinman pulls the lever completely to reverse side, the signal is taken off. After the signal is taken off, the feed goes to the outer signal where a similar reverser is provided. As soon as the outer signal lever is pulled, the electro-magnet is energised and signal is lowered as in use of Home Signal. It will be seen that there is no separate slide for outer signal but is lowered through the same slide used for Home Signal. In case the feed is interrupted anywhere in the entire circuit, the relevant signals will immediately go to danger position. In case the line on which the train is to be received is track circuited, then front contacts of the track relays are included in this slot circuit in the Station Master's office so as to ensure that the line on which a train is being received is clear of all obstructions. These contacts have also been shown in the slot circuit in figure 10. In case any portion of that line is fouled by some movement during the time the signals are in the off position, the track relay shall drop and throw the signals to danger. The coil of this reverser has a resistance of 500 ohms and it takes about 70 to 80 milli amps.

Reversers, indicators and bell relays are all likely to be affected by the induced voltages in the cable. It is absolutely essential to ensure that no reverser are energised falsely so that the signals cannot be lowered when the Station Master has not authorised the Cabinman to lower the signals. Thus the reversers, indicators and the bells are to be completely immunised. A typical circuit diagram showing the proposed immunisation is shown in figure 11 below :

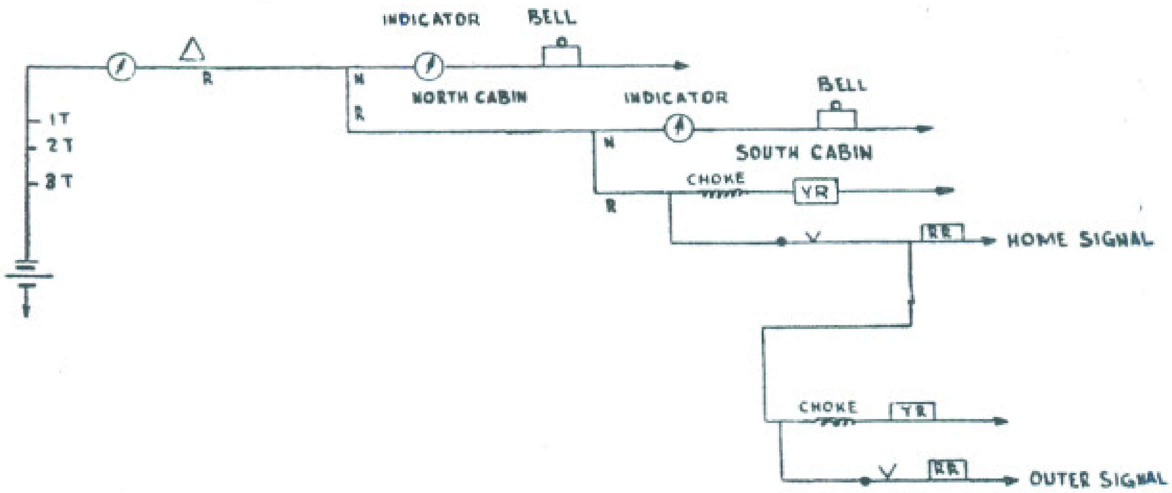

FIG: 11 IMMUNISED SLOT CIRCUIT DIAGRAM

5.3. As will be clear from the circuit diagram, an AC immune DC relay has been provided before the reverser so that when the lever is pulled this relay is picked up first and through the front contact of this relay the reverser gets the feed and the signal can be lowered. As a further safeguard a choke is also provided in series with the AC immune DC relay to ensure that this relay is not falsely energised by the induced voltage and the signal cannot be lowered without the proper authority from Station Master on duty. The same arrangement has to be made for indicators as well as the Bell relay so that the indicators do not operate without pulling the slide in the Station Master's office. It is of course essential that all slot wires which are at present on overhead lines are transferred to the underground so that the amount of induction is reduced to the barest minimum. In certain cases the indicators and bell relays are not immunised with the result the bell rings with induced voltage but the signal cannot be taken off as the relay will not pick up. It is however preferable to have all the relay immunised.

6. Resiting of signals

6.1. Electrification Project involves fixing of overhead electric masts on the entire length from Lahore to Khanewal. These overhead masts create certain difficulties in the station yards so far as the visibility of semaphore signals is concerned. In many cases the overhead masts, cantilevers and insulators etc., completely obscure the semaphore signals. Proper visibility of signals during day and night is essential for safe and efficient running of trains. In order to determine the revised position of the signals a Siting Committee was constituted which visited all station yards and after trials has recommended shifting of certain signals in order to improve their visibility. In certain other cases the signals are to be raised to such an extent that the signals become visible over top of the overhead masts. These signals shall have to be raised to about 40′ from rail level so as to obtain unrestricted view of signals. In certain cases position of overhead masts has also been adjusted in order to provide proper visibility of the signals.

6.2. In spite of thorough examination it is not possible to ensure proper visibility of signals in big yards like Lahore, Raiwind and Khanewal. At such stations semaphore signals have to be replaced with colourlight signals. Colour light signals will be replaced in such a way that they are visible through the cantilever and there is no obstruction at all during day and night. With these additions and alterations it is expected that all the signals will be visible to the Drivers from proper siting distance and no problems will arise. However the Siting Committee will go over the entire section again after erection of overhead masts to satisfy that signals are visible and in case any signals still remain obscure due to the erection of overhead masts, these will have to be suitably shifted or raised so as to improve their visibility.

6.3. So far we have discussed the resiting of signals to improve the visibility of signals from the Drivers' point of view only. The position of these signals in relation to the live conductor carrying 25000 volts has not been taken into account. However it is utmost importance to ensure proper safety of the people working on the signals and it must be seen that none of the tools and other equipment being handled by them while working on the signals does infringe the electrical clearance required for this purpose. Diagrams No. 12-A, 12-B and 12-C on pages 198, 199 and 200 show the minimum clearances required for signals on the electrified lines. In case any signal comes within this electrical clearance, adequate arrangements for screening the signals must be provided for screening purposes. A cage of expanded metal has to be fixed all around the signals so that it is not possible to infringe the electrical clearance by working of the signals. However a better arrangement is to shift the signals to such a place that such screening is not required and the siting of the signals from the approach is also satisfactory. Efforts are being made to shift as many signals as possible to a safe place and to ensure proper visibility in order to avoid infringement of the electrical clearances and the task for providing protective screens. In this connection distances of the signals from centre of the track are to be measured and signals falling within the limits prescribed in the figures 12-A, 12 B and 12-C will be prepared with screens and other protective arrangements.

In this connection distances of all the signals from centre of the track are to be measured and signals falling within the limits prescribed in figure 12 will be provided with screens and other protective arrangements.

Block Instruments

On double line section Lahore to Raiwind, line-clear is at present obtained and given on Tyer's double line block instruments. These instruments work on a single iron wire from one station to the other with earth return. These instruments are highly susceptible to induced voltages and it will not be possible to utilise them after electrification without major alterations at a very high cost. After taking into consideration the cost of immunisation of the existing block instruments, it has been found advantageous to replace these instruments with more modern block instruments manufactured by Messrs. Westinghouse Brake and Signal Company. These instruments have been designed in such a way that these do not need any immunisation for use on electrified lines. These instruments of course work on a pair of lines, will be obtained from telephone cable being laid from Lahore to Khanewal in place of overhead wires.

On Raiwind-Khanewal Section Siemens Tokenless Block Instruments are provided. These instruments have been designed in such a way that these are fit for use on electrified lines. The only modification required is that after

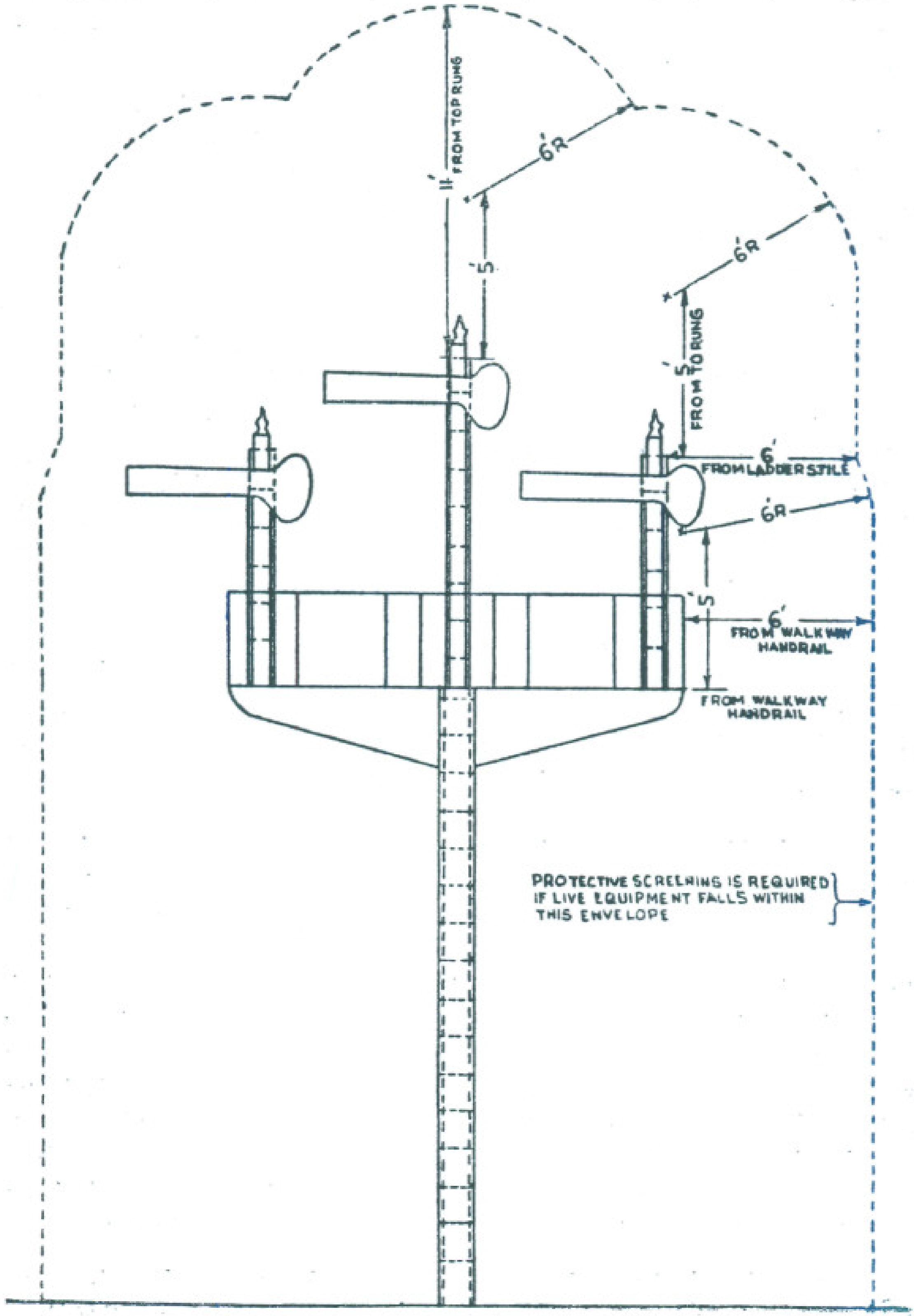
11' FROM TOP RUNG
6'R
5'
6'R
5' FROM TOP RUNG
6' FROM LADDER STILE
6'R
5'
6' FROM WALKWAY HANDRAIL
FROM WALKWAY HANDRAIL
PROTECTIVE SCREENING IS REQUIRED IF LIVE EQUIPMENT FALLS WITHIN THIS ENVELOPE

Fig. 12-*a*.

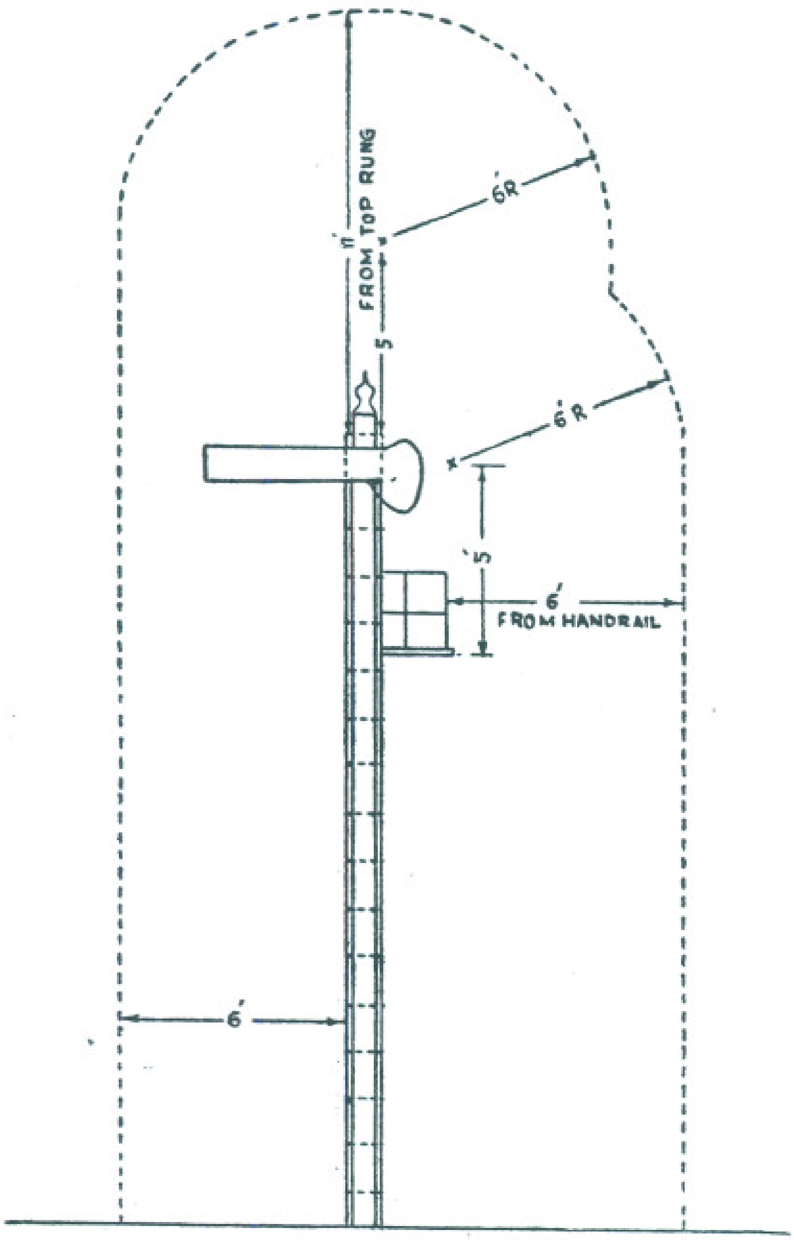

Fig. 12-*b*.

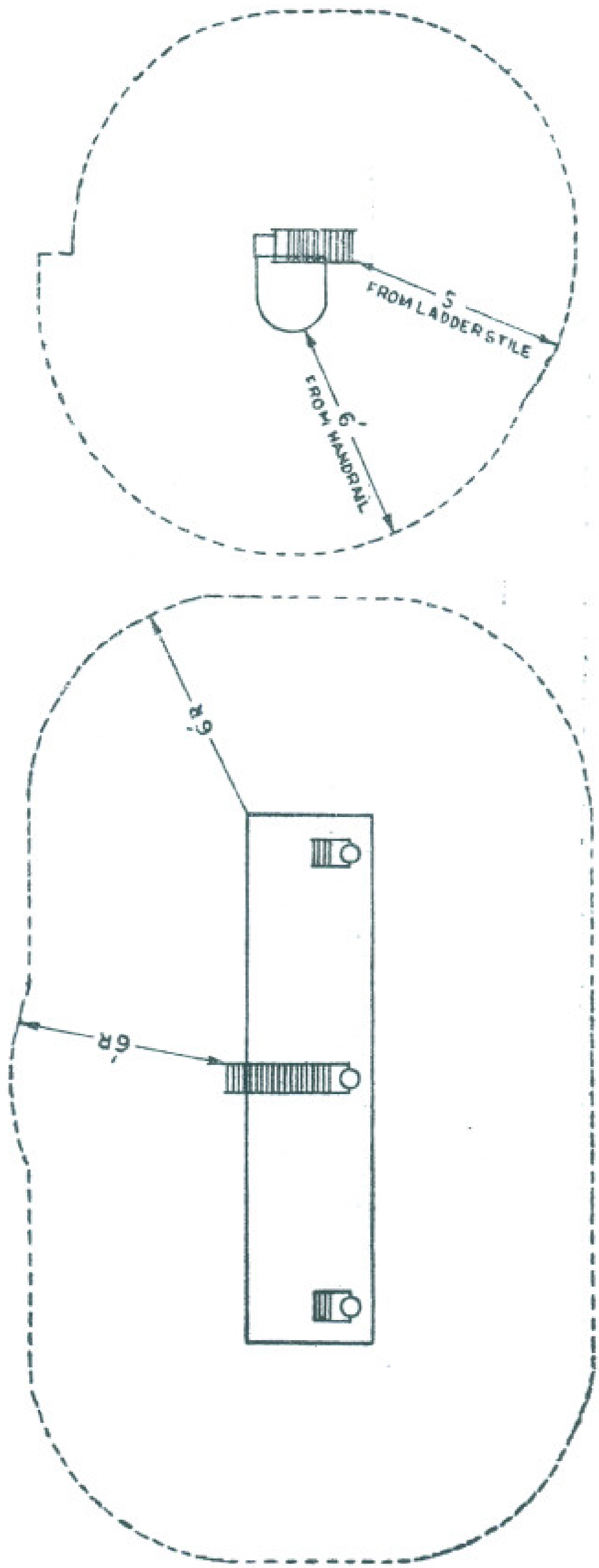

Fig. 12-c.

electrification the instruments will work on metallic return instead of earth return. With the use of metallic return, the diodes of earth instruments shall have to be replaced by a new type. This is necessitated because current in the lines will vary and existing diodes will not be in a position to take. No other modifications are to be carried out in Siemens Block Instruments.

Conclusions. The above discussion gives an outline of the work to be carried out on the Signalling side before electrification work can be brought into use. Safety of train operation is the prime responsibility of a Railway Organisation. Signalling plays a very vital role in ensuring safe and efficient train operation. As a matter of fact Signalling is now considered as the only means by which trains can be worked at high speed with maximum safety. Therefore a system which interferes with vital circuits of signalling thus jeopardising the safety of train operation, cannot be allowed to be introduced on the Railway without taking remedial measures and ensuring that Signalling System operates efficiently under all circumstances and in case a failure occurs it is on "fail safe" principle. It will be ensured that signalling is modified in such a way that trouble-free train operation is guaranteed after introduction of electrification.