Technical Meeting of the Institution

held at

The Institution of Electrical Engineers
Wednesday, February 17th, 1954

The President (Mr. T. AUSTIN) in the chair

After the minutes of the Technical Meeting held on January 12th, 1954, had been read and confirmed, Mr. Broder and Mr. Mattaya, present for the first time since their election to membership, were introduced to the meeting. The **President** also welcomed Mr. H. C. Towers on his return from India.

The **President** announced that the Council had awarded the prize for the best paper read before the Institution during 1953 to Mr. D. R. Turner for his paper on "Interference from Electric Power Lines and Traction Circuits," and the second prize to Mr. F. Horler for his paper on "The Layout of Signal Cabins." He then called on Mr. J. F. H. Tyler to read his paper " Some Signalling Developments on the Western Region 1947-1953."

Some Signalling Developments on the Western Region 1947-1953

By J. F. H. TYLER (Member)

Diagrams—Inset Sheets Nos. 9-14

Introduction

The existence of Automatic Train Control and the very high standard achieved by the operating staff of the former Great Western Railway in the observation of the Rules and Regulations had a great influence on the Company's signalling practice. It is true to say that the operating efficiency was so high that the expense of introducing such betterments as " one acceptance only," sequential locking, " one pull " line clear releases, and the like, was not justified. Semaphore signalling was lower quadrant throughout, and at the power installations at Paddington, Bristol and Cardiff, colour light signals displayed aspects identical with those given at a semaphore installation by night.

In common with other regions, shortages after the war resulted in operating staff having to be placed in positions of responsibility without the long years of experience which had been usual previously, and it became desirable to introduce additional signalling safeguards as and when opportunity offered. At the same time, the operating department began to press for signal box amalgamation schemes to alleviate difficulties arising from the staff position. The signal and telegraph department were also faced with a vast amount of renewal work.

All this meant a very considerable increase in the quantity of electrical apparatus at every new installation and the introduction of methods new to the Western Region. Certain problems at once presented themselves. For example, the operating department needed to be convinced that track circuits could be relied upon as an alternative to the signalman's observation of tail lamps and the motive power department had to be persuaded that, despite right hand drive, colour light signals were best sited at drivers' eye level on the left hand side of the line if consideration was to be given to future locomotive practice. The drawing office, on which the bulk of the work fell, was not easily geared to the production of the modern electro-mechanical installation, owing to shortage of staff and difficulty of recruitment.

For these reasons, progress has had to be slow. Wherever possible, the best of existing practice has been adapted or improved, thus taking advantage of experience gained elsewhere and avoiding a long trial period. Above all, flexibility has been maintained to enable further improvements or additions to be made later. However desirable, standardisation is only a base from which to move forward, but it must exist in the first place or chaos results.

The last five years or so has been an interesting period of signalling development on the Western Region and only a few of the changes can be described in this paper. A very great deal remains to be done but a state has now been reached which may be termed the end of the beginning.

One important investigation which produced an immediate dividend was on coded track circuits.

Coded Track Circuits

Standard bull head track on the Western Region has chairs bolted to the sleeper, the head of the bolt being held in a ribbed plate on the underside. In consequence, steady energy track circuits are limited in length to about 600 yards.

Intermediate block section schemes involve long track circuits and to avoid the many cut sections resulting from the use of steady energy tracks, an experimental coded track circuit was installed by the Westinghouse Brake & Signal Company between Pangbourne and Goring in 1944. This track was 2,080 yards long and worked well enough to justify further installations during 1950 and 1951. The experimental track had relay decoding but subsequently transformer decoding has been used.

The original arrangement of the track circuit used in the 1950-51 installation is shown in fig. 1 in which it will be noticed that a short circuit is applied across the rails during the " off " periods of the code. The purpose of this was to dissipate the " polarisation " voltage which appears across the rails of a long track circuit after energisation.

In practice it was found difficult to avoid occasional failures from varying weather conditions and a thorough investigation was undertaken in the field during the 1951-52 winter.

It was found that the primary cause of the failures was distortion of the code as applied to the CFR, the release of which at the end of each " on " period was delayed by the effect of the shunt path formed by the ballast resistance and the short circuit at the feed end. When the latter was removed the release of the CFR was not appreciably quicker owing to the greater effect of the " polarisation " voltage. This voltage has been observed to be as high as 0·05 and it was clear that it had to be neutralised if an all weather adjustment was to be achieved.

The style B CFR used in the set-up is polar biased. During the " off " period, the armature of the relay returns to the normal or de-energised position under the influence of the permanent magnet. Owing to the " polarisation " voltage and the shunt path across the CFR resulting from low ballast resistance, the coil flux decays slowly at the end of the " on " period and in fact never reaches zero. So far as the armature is concerned, the coil flux and the permanent magnet flux act in opposition and thus the latter cannot restore the armature to normal until the former has decayed to the release value. Under these conditions, the CFR contacts make longer in the " on " position than in the " off " position, which means that the current pulses in the de-coding circuit are uneven and hence the average voltage applied to the TR is less. The failing point of the track circuit is thus reached at a higher value of ballast resistance than would be the case if the code were not distorted.

To neutralise the effect of the shunt path across the CFR, the two members of the technical staff engaged on the investigation hit on the idea of injecting a small current of reversed polarity into the track circuit during the "off" period. The reversed current pulse not only neutralises the "polarisation" voltage but also the slugging effect of low ballast resistance. The voltage thus applied across the CFR in the "off" period causes the coil flux to collapse quickly and build up to a small extent in the opposite direction thus assisting the permanent magnet to restore the armature. The sound is unmistakable and the CFR is said to "tick-tock" when the track is arranged for reverse pulse feed.

The circuit arrangement as finally adopted is shown in fig. 2, from which it will also be noted that it has been found possible to reduce the feed battery to one lead-acid cell. All coded track circuits have since been wired for reverse pulse feed and have remained stable under all weather conditions. High train shunts are not the aim. The operating specification is that the train shunt at infinity ballast must not be less than 0·5 ohm and the track circuit must not fail at a ballast resistance higher than 1 ohm per 1,000 yards. These conditions have been fulfilled on track circuits up to 2,000 yards long without difficulty.

To set up these long track circuits, it was originally the practice to measure the ballast resistance under steady energy conditions with the CFR connected. Resistances were then applied across the rails at each end (a table is available to avoid calculation) to bring the ballast resistance down to 1 ohm per 1,000 yards after which the feed end resistance was adjusted until the TR just operated on code. Latterly, in the light of experience, loading resistances have been applied to the track to give an equivalent ballast resistance of 0·6 ohm and the feed resistance adjusted until the TR is on the point of releasing.

The setting of the reverse pulse feed resistance is not critical. It is adjusted until an even beat on the CFR is obtained. This occurs at 25 to 50% of the forward pulse current.

Television sets in the vicinity of coded track circuits are subjected to interference but this can be obviated by fitting suppression units across CFR contacts IF and IB which energy is supplied to the decoding transformer. It has not been found necessary to fit suppressors to the code transmitter contacts.

The improved operation of the coded track circuit as a result of reverse pulse feeding is shown in fig. 3.

Attractive as it might appear at first, no use has been found for the code itself and the coded track circuits installed on the Western Region are in reality no more than pulse-fed tracks but their use in lieu of steady energy track circuits has been proved to be justified on financial grounds.

In choosing a standard code, two opposing effects had to be considered. On the one hand, a long "off" period assists the release of the CFR under difficult ballast conditions. On the other, the TR operates more efficiently on a short code period, since in any half period it receives the same pulse of energy irrespective of the code frequency and therefore, the longer the half period, the longer must it be held in the energised position by the effect of its slug. The TR is also more affected by code distortion on low frequency codes. After much work in the test room, it was eventually decided to give preference to the operation of the CFR and adopt 75 i.p.m. as the standard code, since it was the intention to code a cut-section track from contacts on the CFR.

Pulse-Fed Track Circuits

The adoption of the pulsing principle for operating long track circuits led to the development and production by the Metropolitan-Vickers GRS Company of equipment specifically designed for the purpose, the general arrangement of which is shown in fig. 4. Essentially the equipment has been adapted from standard relay designs.

The pulse transmitter consists of two mechanically independent armatures on a common magnetic structure. The latter has three cores, that in the centre being common to both magnetic circuits. The two coils, each associated with an armature, are mounted on the outer cores which also have heavy copper slugs.

The operating circuit is arranged so that the armatures interact in such a manner that a contact on one of them may be used to interrupt the track circuit feed at about 50 i.p.m. Rectifiers fitted across each coil provide arc suppression for the armature operating contacts and also assist in delaying the release of the armature. A Mansbridge condenser and resistance fitted across the interruption contacts provide arc suppression for the heavier track feed current.

At the far end, the pulses are received on a 2 ohm pulse-following relay which is of standard design except that a permanent magnet is substituted for the yoke, thus causing the armature to be normally attracted to the pole pieces from which it is released only by the application of current of the correct polarity.

The " de-pulsing " circuit operates as follows. In the de-energised (up) position of the pulse-following relay armature, the electrolytic condenser C_b is charged. When the relay is energised, the armature drops and some of the energy stored in C_b is transferred to C_d. At the same time C_a is charged. When the relay is de-energised at the end of the pulse, C_d receives energy from C_a whilst C_b is again charged.

The TR receives energy direct from C_a and C_b and is maintained in the operated position during the transit time of the pulse-following armature by the energy stored in C_d. During field trials, the pulse-fed track circuit was found to be quite satisfactory for working track circuits of the same length as those operated by coded track circuit equipment.

The pulse-fed track circuit is less susceptible to trouble from pulse-form distortion than the coded track circuit which it must be appreciated was designed originally for a different purpose. This results from the less sensitive " de-pulsing " circuit and the lower pulsing rate. In consequence, reverse pulse feeding has not been found necessary.

On the other hand, when the pulse-following relay is arranged to feed a cut-section track, there is a longer unguarded period between the clearance of the rear track circuit and the occupation of the forward one. The TPR in the signal box must therefore be made slow-to-pick-up to prevent the possibility of an irregular lock release when a single vehicle such as a light engine passes over the intersection of the two track circuits.

Consideration of fig. 4 shows that if the front and back contacts on arms 1 and 4 of the pulse-following relay make simultaneously (e.g. due to welding of the back contact) the TR would remain energised. It is therefore an essential feature of the de-pulsing relay that the contact fingers should be fitted with a guard to prevent the front contact making until the back contact has broken.

Intermediate Block Section Installation

The successful operation of long track circuits on through bolted track enabled consideration to be given to the economical abolition of the many intermediate signal boxes on the Western Region and their replacement by colour light I.B. section stop and distant signals. There were a few motor operated semaphore I.B. section installations in existence on the G.W.R. but all were continuously track circuited to the forward signal box, although operated as forward sections from the rear box. The limitation on track circuit length meant in some cases up to 12 cut-sections on each line, which was obviously not economic.

Fig. 5*a* shows the elements of the I.B. section installations as installed by the G.W.R. and fig. 5*b* shows the original proposal for colour light installations. The latter contained only the essentials and relied on the existence of sequential locking and block interlinking at the rear box. It was, however, laid down by the Railway Executive that the colour light distant signals must be replaced by track circuit to ensure compliance with Rule 68; and also that a " train running away " audible warning must be given to the signalman in the event of a train running past the stop signal. The essentials of the scheme finally adopted are shown in fig. 5*c*.

The Western Region has now embarked on a programme of replacing all intermediate signal boxes by colour light I.B.S. installations. The first stage of this work involves the abolition of 23 signal boxes and the saving of 54 signalmen.

The elements of the control and indication circuits are shown in fig. 6. Several new features have been introduced into the indication circuits. Two-aspect multi-unit signals are employed and independent double filament lamps are used for the first time on the Western Region. The lamps are rated at 12 volts, 16 watts (main filament) and 24 watts (auxiliary) filament.

There are three indication circuits. One indicates the failure of a main filament or the power supply at either signal. The other indicates, separately, the failure of both filaments at either signal. The polarised aspect indication circuits are combined with the latter. No attempt has been made to indicate the state of filament in the cold condition as it is considered that the presence of auxiliary filaments and the proving of aspects " on " before the semaphore signal can be pulled, forms an adequate safeguard.

Referring to fig. 6, the failures of either main filament or of the power supply causes needle indicator 12 ZK to move from " normal " to " standby in use." This is a warning to the signalman that the lineman must attend within 12 hours in case it is the power supply which is at fault. The battery capacity is, however, such that the installation should function satisfactorily for at least 24 hours.

The failure of both filaments of a lamp causes needle indicator 12 GK or 12 PGK to show " light out " after which semaphore signal No. 11 cannot be pulled if the lamp concerned is in the red or yellow aspects. This obliges the signalman to observe Rule 81. If, after obtaining " line clear " from the box ahead, he finds that the I.B. signals clear correctly, the minimum of delay is imposed by the failure. If, however, the lamp concerned is in one of the green aspects, safety is assured in the event of a run by, as the line has been proved clear by the block acceptance.

The only other feature to be noted is the use of a neutral-polar relay 12 G/ECR to control the I.B. distant thereby saving a line wire between the two signals, as it enables the stop signal aspect indication circuit to be fed from the distant signal.

The usual independent telephone circuit is provided between the stop signal and the controlling signal box, but a pair of terminals in the distant signal apparatus case is connected to the circuit to enable the lineman to use his portable telephone for communicating with the stop signal or signal box for maintenance purposes.

As the I.B. stop signal is generally about 2 miles from the controlling signal box, an audible warning is given to the signalman as the train passes that signal, so that the sending of the " train entering section " signal shall not be delayed. This warning is given as a short buzz.

The " train running away " warning is given by the same buzzer sounding continuously until cancelled by the signalman. Failure of the " train running away " warning would constitute a wrong side (unprotected) failure and so, to reduce this possibility as far as practicable, a common circuit for both " train entering section " and " train running away " warnings has been designed using the principle that as great a part of the " train running away " circuit as possible is used for the " train entering section" warning. As the latter functions for every train, a regular check of the circuit is obtained.

The number of installations to be dealt with enabled the apparatus cases to be manufactured, assembled, wired and tested on a mass production basis in the Western Region Signal Works at Reading. The apparatus cases, constructed in sheet steel on an angle iron framework, are welded throughout. Each case has two compartments with separate hinged doors. The battery of lead-acid cells stands on bitumen treated wooden shelves in the left hand compartment and a backboard carries the apparatus in the other. The apparatus is assembled and wired on the backboard before being fitted in the case.

A casting bolted on top of the case carries the short tubular mast on which the 2-aspect multi-unit signal head is mounted. The engineman's telephone, required on stop signals, is fitted in a separate sheet steel case with a lift-up cover and is mounted on the end of the apparatus case.

In four-line layouts, or in cases of special site difficulty, the apparatus case may be fitted with a standard blanking plate on top and the signal mounted on a separate concrete base between tracks.

Manganisite paste, reduced to a suitable consistency with boiled linseed oil, is used to seal the joint between the casting and the top of the apparatus case and has proved satisfactory in preventing moisture entering the interior. The cases were painted before assembly with one coat of red lead, one coat of micaeous iron ore and a finishing coat of synthetic aluminium. This protection has given every satisfaction to date.

As previously mentioned, wiring of the case has been carried out on a mass production basis. The complete case wiring is formed and laced up in a jig which is adaptable to both stop and distant signal wiring.

After assembly and wiring, the cases are tested in pairs in the shop from a mobile test bench. The test bench, in addition to containing all the associated apparatus at the signal box end is also fitted with stop and distant signal lamps, each filament of which may be disconnected as required. By this means, a full test of a pair of apparatus cases may be completed in ten minutes.

After testing, the larger relays are removed and the cases loaded for dispatch, complete with signal heads, masts, ladders, identification plates and all fixing bolts.

Power supply generally is at 110 volts a.c. but in some cases 230 volts a.c. is necessary owing to line drop. To enable standard apparatus to be used in such cases, the signalling supply from the telegraph route is reduced to 110 volts at a step-down transformer mounted at the foot of the pole.

In other cases, surprisingly few, a power supply is either not available or cannot be provided economically. Approach lighting from primary batteries must be resorted to and in order to maintain the lamp proving circuits for the signalman's benefit, the lamp proving relay has a high and low resistance winding, so that when the approach track circuit is clear, it remains energised on a small proving current passing through the cold filament. The circuit element of this arrangement as applied to a colour light distant signal is shown in fig. 7.

The mass production of the apparatus cases in the works has proved successful and economic, reducing as it does weather delays and walking time which can be a heavy item of expenditure in a long section.

Multiple Aspect Signalling

The need to renew the colour light stop and distant signalling between Paddington and Southall West Junction, a distance of 11 miles, provided the first opportunity to introduce multiple aspect signalling on the Western Region. The original proposals, involving a number of power boxes, were considered too costly and a scheme had to be developed which could be carried out at a cost approximating to that for a like-for-like renewal. This meant the retention of the existing mechanical signal boxes except where an exceptionally good financial return from amalgamation could be predicted. It also meant that as much as possible of the existing equipment had to be reused. It was therefore decided to adapt the existing searchlight signals to 4-aspect signalling and retain d.c. track circuits except in one case which will be referred to later. All existing equipment to be reused had to be completely stripped and overhauled, before being installed again. Cost, being the foremost consideration, considerable ingenuity has been necessary in adapting the existing material to the requirements of a modern installation.

The existing Type SA searchlight mechanisms, for instance, displayed two aspects only and had a single set of proving contacts. The lamp and aspects were indicated in the signal box on a 2-element 3-position relay, the control winding of which was fed from a transformer connected in series with the lamp as shown in fig. 8.

To gain sufficient searchlight signals for the first stage of the work, existing timber brackets carrying splitting signals were replaced by junction indicators and stop and distant searchlight signals on tubular steel posts. The mechanisms thus made available were stripped in the works and reassembled with sets of modern double contacts and plug couplers which had been purchased. Type W single yellow units were also purchased and mounted on a new background plate with the old mechanism case to which a new cast iron door was fitted to gain clearance for the plug coupler. By this means a modern 4-aspect searchlight unit was produced at moderate cost.

To enable the original lamp proving circuit to be used, thereby avoiding the purchase of new transformers and relays, single filament 12 volt 12 watt SL 16 lamps were retained in the searchlight mechanisms. An additional relay for lamp proving (ECR) was introduced into the circuit as shown in fig. 8. This relay is necessary to enable the lamp filament to be proved in the rear signal mechanism control circuit and must remain in the energised position during the changeover from yellow to green. The combination of a 62·5 ohm Style D relay and a SD 133 bridge rectifier rated at 12 volts 70 milliamps was found to be adequate to cover the maximum changeover time of 300 milliseconds without the introduction of an inherent slow release feature on the relay. The maximum changeover time occurs at the far end of the 460 volt signalling supply cable when the standby generator is in use.

Referring again to fig. 8, it will be observed that any particular signal (which is " off ") goes to green on the operation of the HHR at the signal next ahead. The HHR is fed over contacts on the R/HDGPR's of the latter signal and the signal farther ahead. The R/HDGPR's being 3-position relays release during the changeover of the mechanism contacts and the HHR must be made slow-to-release to cover this period. Unfortunately, when signal aspects are changing the R/HDGPR's do not release simultaneously and in consequence it was necessary to increase the releasing time of the HHR to about 0·9 second to cover a double changeover period and contact bounce.

The circuit, which is unusual, was adopted after full scale trials in the test room and has given very little trouble.

The very close spacing of some of the signal boxes on the Paddington-Southall section and the revised location of signals led to another unusual difficulty. Generally speaking, each box had a home and a starting signal originally but the spacing of the multiple aspect signal on a time/distance basis resulted, in many cases, in the provision of only one controlled signal on a particular line. To cover the operating requirements in regard to shunting movements and " delayed yellow " control approaching restricted overlaps, a somewhat involved system of forward and rear slotting had to be introduced. A typical case is shown in fig. 9.

The slotting and restricted overlap working led to complicated controls and so, to avoid possible misunderstandings with the operating department, a set of principles in diagrammatic form were drawn up and agreed at the outset of the job.

A further innovation with the object of reducing the cost of track circuit indications in the rear of a signal box, was the introduction on the illuminated diagram of an "approaching train" indication. The object of this indication is to warn the signalman audibly and visibly that a train approaching his signal box, will be checked at a double yellow aspect unless he clears his signals. The circuit elements of this feature are shown in fig. 10.

Another feature, associated with delayed yellow aspects, is the indication of a restricted overlap to the signalman in rear as a track occupied irrespective of whether the restriction is due to track occupation or points reverse. This is justifed on the grounds that it does not concern the rear signalman by what means the overlap has become restricted.

Throughout the installation, separate auto. switches are being provided for through working on each road. These switches have averaged a saving of 50-80% of the signalman's physical work in that portion of the job which has been completed.

At each signal box, a relay room has been provided by building a brick extension of the lower floor with a flat roof. This houses the new equipment on modern steel racking. Detachable tops are provided on all a.c. relays and all purely indication relays are of the telephone type.

At West Ealing, an amalgamation scheme has been developed enabling four signal boxes to be closed. At this box, a panel fitted over the levers will control the power-operated points and signals on the entrance-exit principle. The scheme, by itself, does not justify route working but is being carried out to gain experience for a much larger scheme elsewhere.

The track circuits at West Ealing are a.c., condenser fed and all relays in the relay room are plug-in Type B. An unusual feature is the use of soldered connections to the relay plugboards with the object of overcoming space difficulties arising from the use of standard O.B.A. terminals. It is not intended that soldered connections should be used except in the relay room where the joints may be made with electric irons under ideal conditions.

All signals have been assembled and wired in the works to minimise work on site. The wiring is terminated on O.B.A. terminals in a sheet steel case clamped to the foot of the post. In the case of bracket signals, the top member only is assembled and wired.

Signal bases were at first made from concrete mixed on site but a great saving in time has resulted from having concrete ready mixed in ballast wagons. By this means, a base for a bracket signal taking 6 cubic yards of concrete can be poured in about 20 minutes.

Automatic Train Control is provided at each multiple aspect signal, the ramp being sited about 200 yards on the approach side of the signal. The bell indication is given on the engine approaching a signal at green and a siren warning and brake application approaching a signal at double yellow, single yellow or red.

The cost of automatic storage type train describers was found to be prohibitive for the Paddington-Southall scheme but by a fortunate coincidence, the temporary describers developed by the Siemens & General Electric Railway Signal Co. for the Liverpool Street-Shenfield electrification scheme came into the market. They were purchased, overhauled and adapted to the different conditions obtaining on the Paddington-Southall installation.

These describers, shown in fig. 11, have the virtue of extreme simplicity, the unique feature being that the signalman does his own storage. They have a capacity of 20 different descriptions, and descriptions for five trains may be stored and displayed. All apparatus is of standard telephone switchboard pattern.

Eight line wires are required: lines 1, 2 and 3 being used for descriptions 1 to 8; lines 4, 5 and 6 for descriptions 9 to 20; and lines 7 and 8 for selecting the display panel (i.e., main or relief) and for returning the acknowledgment signal. The descriptions are selected at the receiving end by the combination of the polarities on the three lines concerned.

On receipt of the description, the signalman puts it on the storage lamp group by pulling out the appropriate key before acknowledging to the rear box. Acknowledgment cannot be sent until the description has been stored. Train order lamps indicate to which train the description refers and on clearing out the first description, the train order lamps automatically indicate the next description as the first.

These describers have worked well since installation and there have been very few failures. The Author is of opinion there is a field for a simple describer of this type in many multiple aspect schemes where the cost of the automatic storage type cannot be justified.

Enginemen's Telephones

The standard telephone at signals on the Western Region is a local battery type. The number of signal post telephones on the Paddington-Southall installation was, however, so great that battery maintenance would have been a nuisance. The number of telephones to any one signal box on the other hand did not justify a selective calling type.

It was therefore necessary to develop a system using ordinary C.B. telephones to fulfil the following conditions :—

(*a*) Ringing tone to be returned to the driver to advise him that the signalman was being called.

(*b*) An audible warning to be given to the signalman in the event of his not replacing the " speak " key after the driver has replaced his hand set.

(*c*) An audible warning to be given to the signalman in the event of the driver not replacing his hand set and means to be provided to cut out the calling signal in these circumstances.

(*d*) An alternative calling method to be available to the driver in the event of the previous driver not replacing the hand set on the cradle.

(*e*) No overhearing between circuits.

(*f*) The provision of a signal box concentrator fulfilling the above conditions.

Fig. 12 shows the circuit elements of the arrangement finally adopted. Points to note are the return of ringing tone to the driver via the transformer, the auxiliary circuit to the calling buzzer which is made up if the " speak " key is not replaced after the driver has replaced his hand set, the auxiliary bell which advises the signalman that the driver has not replaced his hand set and the facility to call the signalman by " flashing " the auxiliary bell by means of the cradle. The auxiliary bell is brought into use by throwing the " cut-out " key.

Protection of Personnel Working on Supply Mains

During the course of the Paddington-Southall installation, the existing 460 volt signalling supply cables were taken over by the signal and telegraph department which had not previously maintained power supplies higher than 110 volts. It was therefore thought desirable to provide a form of protection for jointers working on the 460 volt cables. A cheap and convenient means of protection was found in the use of Castell locks fitted on the circuit breakers.

When it is necessary to work on a particular section of the supply cable, the circuit breakers at each end of it are thrown out after which the Castell keys may be turned and withdrawn, thus preventing the breakers from being restored. The keys have various alphabetical configurations and one is allocated to each section of cable. Two keys of the correct configuration must be withdrawn by the jointer before the work is commenced.

Relay Room Equipment

The increase in electrical apparatus meant that, on most jobs, a relay room has had to be built as a ground floor extension to the existing signal box. This was an innovation for the Western Region except for power installations and has meant the design and development of a complete set of standard racking. It was decided at the outset that all racking should be open and that wiring should be treed and laced throughout. The high cost of treeing and lacing was felt to be justified as the price to be paid for neatness and cleanliness during the lifetime of the installation.

The standard section of relay racking shown in fig. 13 is 4-ft. long and has adjustable wooden shelves and provision for back-boards for polar and telephone type relays. It is designed to stand away from the wall, although, where space is restricted, it can be adapted to fit against the wall. It is constructed in mild steel sections and, being jig-made in the works, can be sent to site as a set of parts, thus facilitating transport. As many racks as required are bolted together. Each rack carries its own portion of strapping for the main wiring trees and it is only the cross straps to carry the wiring to the wall which are made specially to suit local conditions.

The standard cable termination is also designed on the unit principle but for wall fixing. Each section is 3-ft. 3-in. long and is capable of accommodating three 37-core cables. Each section comprises the cable termination racks on which are bolted O.B.A. terminal blocks and links, a length of strapping for the main wiring tree and similar lengths carrying the cable potheads and clamps.

Fuse and busbar racks are also designed for wall mounting but, in this case, flexibility in the number of fuses, busbars, etc., is essential as no two jobs are alike in this respect.

The adoption of these standard components, all of which are stocked in the stores, leaves little to be manufactured specially. Fig. 14 shows the cable rack and the fuse and busbar rack and a typical power supply rack designed on the same principle. Relay room layouts are designed in the drawing office and special ironwork ordered direct on the works.

In cases where the amount of apparatus is considerable but for one reason or another a relay room is not, or cannot be, provided, a set of racking on the unit principle has been designed for fitting in the under-portion of the signal box. The relay, cable and busbar sections can be made up as required and bolted together, the whole being covered with standard sections of hardwood bolted to the framework. Glass fronted lift-off doors are fitted on each section. Although somewhat vulnerable, it is preferable to fit glass to the doors rather than to encourage an out of sight out of mind complex amongst the maintenance staff.

Layout of Signal Boxes and Relay Rooms

The practice on the G.W.R. was for the locking frame to be positioned so that the signalman faced the track. It having been decided that new locking frames should be installed so that the signalman has his back to the line, the opportunity was taken, in conjunction with the architect who took over the building of new boxes from the signal and telegraph department, to introduce improved arrangements and amenities.

Fig. 15 shows the layout adopted in a typical case where a relay and battery rooms have been incorporated in the structure. Steel trusses have been used in place of timber for supporting the locking frame.

The layout of signal boxes and relay rooms is planned in the drawing office, careful attention being given to wire runs, lighting, heating and the provision of good accommodation and amenities for the linemen.

Fig. 16 shows the layout of a large relay room now being built for Birmingham (Snow Hill), where Type B plug-in relays will be used throughout.

Colour Light Distant Signals

The introduction of colour light distant signals on the Western Region presented no technical difficulties as the circuits followed closely the principles adopted for I.B. signals. Quite a number are now in service but so far only isolated signals have been dealt with because it has been necessary to deal with the greatest number in the shortest time. To deal in the early stages with lower distant signals would have caused delay not only because of the more involved installation work but also because other problems arise such as the conversion to colour light or power working of the distant in the rear and the possibility of reading through leading to the conversion to colour light of other signals. Such proposals tend to spread and quite a large job often results from the renewal of one signal with a lower distant in colour light form.

As the wiring associated with isolated colour light distant signals is comparatively small, there is no economy to be shown in pre-assembly and pre-wiring in the works, and standard line-side apparatus cases have been wired on site.

Use of Mechanical Plant for Installation

During the past five years or so, a special endeavour has been made on the Western Region to ease and reduce the work of men engaged on installation. Pre-assembly and pre-wiring are the rule wherever practicable but there is a limit to what can be done in this direction. In addition, the policy is to introduce as much mechanical plant as can be justified.

Each inspector's district now has at least one portable Maudsley generator set to provide power for drilling machines, power hammers and flood lighting. Each set comprises a twin cylinder Douglas 4-stroke O.H.V. petrol engine direct coupled to a 2·5 k.w. d.c. generator. Petrol consumption is about 1/3 gallon per hour.

Each district has also at least one petrol electric rail drilling machine for bonding. This machine, which was developed and designed by the Western Region, is manufactured by Welco Farm Implements Limited. It comprises a Tarpen 2-stroke petrol engine driving a 500 watt 2,500 r.p.m. generator which supplies power via a 3-core tough rubber cable to a light and compact twin-spindle electric drill. The drill has a cam-actuated clamping device which fits under the rail and it may, in emergency, be left *in situ* without harm during the passage of a train. Two holes are drilled in the rail simultaneously in about one quarter of the time taken to drill one hole by a hand bonding machine. The generator set is mounted on two rubber-tyred wheels and the drilling machine when not in use is carried on it. The generator set weighs about 50-lbs. These machines have greatly reduced the physical work of bonding long stretches of line and are well liked by the men. The generator, which has a petrol consumption of about ⅛ gallon per hour, may also be used for supplying power to portable electric drills, e.g., those used by locking fitters.

For digging in hard ground, Warsop petrol driven breakers are available and have proved to be of great assistance in burying cables under the track.

Power driven augers have also been used with success for digging holes for telegraph poles and developments are in hand for the production of a rail mounted machine which will dig holes for signal posts as well.

All electric tools are 230 volt a.c./d.c., thus enabling a local power supply to be used wherever available and reducing the weight of machine and cables as compared with 50 volts.

Use of Radio

The Author has always felt that radio communication would justify itself in the saving of time during the installation and testing of signalling work and during 1953 authority was given for the purchase of seven walkie-talkie and three mobile sets from Marconi Company. These sets operate on a single frequency in the 80 megacycle band. The walkie-talkie sets weigh $14\frac{3}{4}$-lbs. including the single lead-acid cell required to supply the vibrator power pack. The mobile sets comprise a transmitter/receiver unit with a separate power pack which may be of the vibrator type fed from a battery of 6 lead-acid cells or of a type fed direct from the mains. The practical working range between walkie-talkie sets is about $1\frac{1}{2}$ miles and between walkie-talkie and mobile sets about 2 miles. These distances may be greater under favourable conditions but very much less if the sets are screened by a building or a vehicle. Experience in working the sets soon eliminates most of the trouble with screening.

Since their arrival the sets have been used extensively and have saved a considerable amount of time on track circuit testing, alignment of colour light signals, aspect sequence testing and any other work necessitating communication over a distance. They have eliminated the provision of temporary telephones for work of this nature.

They have also proved ideal for the type of communication required during the bringing into use of signalling installations over stretches of line up to about 5 miles in length.

During the changeover of the first stage of the Paddington-Southall re-signalling, the work of some 200 signal and telegraph staff was successfully controlled by radio from a saloon coach which acted as a control centre. Once radio has been used for this kind of work there is no question of a return to the old system of field telephones and the relaying of messages.

Conclusion

The last five years have seen the beginning of an endeavour to bring Western Region signalling practice more into line with the modern outlook. This is not to decry the practice of the old Great Western Railway which was established on the solid foundation of operating efficiency, but the tendency nowadays is to guard as far as practicable against a failure of the human element and in this direction the old standards have had to be revised. In undertaking this work and laying down new standards, we have had the great advantage of being able to adopt and try to improve the best of existing practice wherever applicable. More could have been done had not the technical staff shortage been so acute.

In conclusion, the Author wishes to pay a tribute to his Chief, Mr. A. W. Woodbridge, for the fresh outlook he brings to every problem and for the great encouragement he has given to the testing and introduction of new methods. He also wishes to thank the staff of the department in general and Messrs. Claridge, Cardani and Farrell, in particular, for the enthusiasm they have shown and the long hours they have spent in achieving the desired result.

DISCUSSION

Opening the discussion, **Mr. A. W. Woodbridge** said that, today, one was not thinking in terms of whether one should introduce this or that, but how it should be put in, as the problem was largely a financial one, and it was essential to pay the closest attention to the details of installation in order to keep costs as low as possible. The paper stressed some of the complications the Western Region had to meet on the Paddington/Southall scheme. It had been the intention to make full use of centralisation, but owing to financial restriction, a great deal of ingenuity had to be brought to bear which resulted in the development of the ideas which the author had so ably described. Mr. Woodbridge took the opportunity of paying a tribute to all members of his staff, who had worked under extreme difficulties, but had all displayed great enthusiasm over the work.

Mr. J. H. Fraser said that he agreed with the statement in the paper that "standardisation is only a base from which to move forward," and one could see at a glance that the Western Region were going forward at a very rapid pace. They were not afraid of thinking well ahead, particularly where the design of track circuits was concerned. The enthusiasm of the staff, which Mr. Woodbridge had mentioned, was, in the speaker's view, entirely to the credit of the leaders of the department.

Mr. L. J. M. Knotts said that he also was impressed with the attitude taken towards the type of track circuit to be used to compensate for the handicap imposed by the use of fang bolted track. There were many d.c. track circuits using ordinary apparatus up to 1,500 yards, and even longer. He suggested that although the pulse track circuit might be more expensive, the civil engineer should be ready to give them more consideration, in view of the fact that there were thousands of miles of track circuits yet to be installed. The standard flat bottom track with ordinary spikes was ideal for their purpose, and he hoped that the signal engineer's task would not be made harder and more costly, which might result if through-bolted track were perpetuated. Mr. Knotts raised the question of sleepers being treated with salts, which had caused a good deal of trouble with track circuits and had given rise to the use of the pulse track circuit.

With regard to A.T.C., he assumed that as drivers were used to the ramp on the approach side of distant signals, they were not finding any difficulty between Paddington and Southall with the multi-aspect, colour-light signals.

Mr. A. Moss was particularly interested in the mechanised methods described, and agreed that such arrangements could do much to bring down costs.

Many on the Eastern Region would recognise the lantern slide of the train describers and he congratulated the Western Region on the way they had adapted them for their purpose

He liked the pre-wiring of signal cabins and the testing in the shops, and hoped that in the development foreshadowed by the author, greater use would be found for a less expensive type of relay, as he thought there was scope for that in the less important parts of a circuit.

Mr. J. P. Coley commented that, in the paper, the coded track circuit and the pulse-fed track circuit were shown under quite separate headings, which gave the impression that they were different sorts of track circuit. He thought such was not the case and they were fundamentally the same type. Two different arrangements were shown of the decoding and, as the author put it, they were fundamentally the same. The coded track circuit was originally designed, for a different purpose. That was to use a number of codes for controlling multi-aspect signals over running rails, with a view to effecting economies in line wire. For multi-code working, the de-coding transformer arrangement of de-coding was essential, because it was necessary to produce different frequencies for operating tuned circuits for separating the different code speeds. Furthermore, the transformer decoding arrangement—shown in figs. 1 and 2—had certain advantages which were inherent in it and, which could not be obtained so easily with other arrangements. In view of these, it was reasonable that the transformer coding arrangement should be employed when it came to working pulse code track circuits. However, experience had shown, and the author had pointed out, that the transformer de-coding was more susceptible to code distortion than the other forms of de-coding or de-pulsing. That was because the output of the de-coding transformer to the TR was dependent on the relationship of the "on" period of the code and the "off" period, and they could get the maximum output when the two were equal.

Code distortion had been brought very much to the fore in the paper. There were three factors to consider :—

(1) Variation in balance ;
(2) Value of polarisation voltage ; and
(3) Value of feed resistance and supply voltage.

These factors affect the time pulse of the circuit and therefore the time it takes for the current to build up to the pick-up value of the relay and to decline to the drop-away value. Of these three effects, the Western Region have found that polarisation is the most difficult one to cope with. This is caused by energy stored in the track circuit during the "on" period of the code passing through the relay during the "off" period and tending to hold the relay energised. The Western Region had found an ingenious solution to the problem by applying a reversing impulse during the "off' period of the code, which stablilised the operation and gave substantially equal "on" and "off" periods in the circuit; but, when it was known just what had to be met with regard to the polarisation voltage and also with respect to balance and resistance variation and feed voltage, there was actually no difficulty in designing a suitable code following relay to enable the transformer de-coding method of operation to work over the maximum range of distortion likely to arise. That would then eliminate the necessity for the extra circuit and the extra resistance. The principle required to do that was to provide a relay whose sensitivity was reduced, so that the pick-up and drop-away values of the relay were appreciably above the polarisation voltage. That actually must apply to any form of coding. It was undoubtedly true that the de-coding method was slightly more susceptible and required a larger difference between its operation figure and polarisation voltage than would be the case for other forms of coding.

It had been stated in the paper that, for the pulse-fed track circuit, relays and transmitters were adapted from standard designs. He asked if the adaptation included the use of pivoted bearings, as he was of the opinion that in the case of apparatus with moving parts operated many millions of times in a year, it was preferable that moving parts be hinged on metal ligaments rather than be on bearings. If bearings were used, it became essential to reduce the code speed to a minimum, which introduced the risk of increase of the unguarded period in the case of cut sections, to which the author had referred. The unguarded period could only be minimised by the use of a high-speed code.

He emphasised that the question of the polarisation effect, causing code distortion and leading to other difficulties, was confined to d.c. coded track circuits or any type of pulse track circuit, and would not be a phenomenon one would meet with on an a.c. track circuit. With the latter, there would be no difficulty in employing transformer de-coding methods of working. That would have the advantage of enabling other codes to be added later should they be required.

Mr. J. C. Kubale said he was a little surprised that the polarisation voltage was so small as the author mentioned; and from the paper, it was not quite clear whether the loading resistances, which were inserted, were only for test purposes or whether they were left in the circuit.

He was also surprised that no use had been found for the code itself, because it seemed that there were possibilities there of further economics being made. First having overcome the difficulty of coding the pulsating track circuit, it would seem that the next step would be to use the codes, first in a downward direction, and later for a reverse direction or for the elimination of line wires. It was used in other countries and it would be very interesting to know why the author thought there was no use for it in this country.

With regard to concrete signal bases, he had observed in South Africa recently the use of concrete reinforced with steel and disused signal wire. By that means, about half the weight of concrete was needed, and being pre-fabricated, it seemed to be an admirable idea for the railways to consider.

He wondered why the author had not introduced a photograph of the signal box illustrated in the press recently, and he would like to know what was the advantage, or otherwise, of that signal box.

Whilst appreciating the mechanical aids available nowadays for installation work, he would like to know by how much they improved efficiency. What was the overall cost and maintenance of the mechanical equipment, as compared with what might be called the old-fashioned methods?

With regard to radio, one could appreciate the great advantage of the use of it, and he asked how stood the railways with the Post Office authorities regarding its use for such purposes?

With regard to the author's statement that "more could have been done had not the technical staff shortage been so acute," there were technical organisations which were only too willing and able to help the railways in their construction and installation problems, as they had helped in the past. Perhaps they had not been called upon to the full in the period since the war because the railways had not the money and the opportunity to take advantage of the manufacturers' help.

Mr. H. J. Riddle, in referring to diagram 3, said that it showed, in effect, the shunt values obtained on two different codes under different conditions. The author had given some idea of the criteria which was adopted to decide whether a track circuit was properly adjusted or not. If both frequencies had to be accommodated, would there be any possibility of doing so, if three codes were concerned or would the difficulties be insuperable?

Mr. J. E. Mott asked for more information as to the maintenance of the track circuits and how reliable they were. He thought that one was left with the impression that the simple pulse track circuit was better economically than the coded track circuit.

Referring to the train describer installation, he thought it might be prudent to consider the amount of money that must be spent in workshops for overhauling the apparatus. Often new equipment was much cheaper than taking old equipment and converting it, and at times the final cost might be a great deal more than it appeared to be.

Mr. J. H. Currey said that the coded track circuit, as mentioned in the paper, was designed for a different purpose to that for which it was used, and naturally it was expensive when it was merely required to overcome the difficulties of long track circuits with poor ballast conditions. That was where the Western Region had so admirably produced the very much simpler pulse arrangement, which was designed for its purpose. The accurate length of the pulsing was not important, as only one pulse was required, and he considered that conditions now, with the advent of the pulse track circuit, should make its use much more feasible on long I.B. lengths, which was prevented by the high cost of the original coded track circuit, with all its advantages which were not actually required. He would like to see the use of the pulse-track circuit extended and asked if the author could give more figures relating to its actual performance.

Mr. L. G. Smaldon, referring to mechanisation of tools, stated that, on one Region, there was a rule that all portable tools must not be more than 50-v. working, and he asked if this was followed on the Western Region.

Mr. B. F. Wagenrieder said it mentioned in the paper that the ramp of the automatic train control was placed 200 yards on the approach side of the signal, but he thought that the Western Region placed their ramps ahead of the signal.

The **Author**, in reply, thanked Mr. J. H. Fraser, Mr. A. Moss, and Mr. A. W. Woodbridge for their kind remarks on his paper.

Replying to Mr. Knotts, he said that if the standard minimum shunt of 0·5 ohm was to be maintained, the maximum length of a steady energy d.c. track circuit on screw fastened track was about 1,200 yds. On fang-bolted track the maximum was about 600 yds. and therefore at an I.B. section installation there might be three cut-sections between the I.B. stop and distant signals and four or five between the latter and the rear starting signal. Solely on capital expenditure the coded or pulsed track circuit had been an economy but the saving in maintenance in addition was very great indeed. He agreed that as more flat bottom track was laid, the steady energy track circuit would be used to a greater extent in these installations.

With regard to tanalith impregnated sleepers, they had carried out tests over a long period on the Western Region on behalf of the Civil Engineer for the information of the company producing the salts. These tests had shown that the salts, in their present form, brought down the rail-to-rail resistance to too low a value for practical working of track circuits.

In reply to Mr. Coley, he agreed that, in principle, moving parts on a hinged ligament seemed better than if carried on pivoted bearings but, in practice, it was not pivot wear but contact wear which determined the life of the code or pulse-following relay. No trouble had been experienced with pivoted bearings. He agreed that polarisation difficulties could probably have been overcome by suitably designed equipment but the difficulties had been found after standard equipment had been supplied and the solution, in the event, was simple enough.

In reply to Mr. Kubale, the loading resistances were applied to the track circuit to bring the ballast resistance down to about 0·6 ohm. After adjustment of the feed resistance, the loading resistances were removed. As regards using the available codes, they had constantly looked for an application but unfortunately it seemed that whenever information was required to be transmitted the track circuit was occupied. In I.B. section installations, too, distances were comparatively short and it was doubtful whether the extra cost of multi-code transmitting and de-coding equipment would outweigh the saving in line wire cost.

On the question of concrete bases, they had considered precast and reinforced bases but there was a lot in favour of casting on site because then the base is in firmer ground. The signal box referred to by Mr. Kubale was the first on the Western Region to be designed and built by the Architect and contained a number of experimental features. Mechanical aids were not used to the exclusion of manual labour but whenever justified economically. For example, it might take a gang two days to dig a hole for a signal but with a power auger it was only a matter of minutes. Regarding radio, the Postmaster-General had allocated a frequency band for railway purposes and no difficulty had been experienced when an approach had been made for licences. The manufacturers in this instance had been very helpful. It was agreed that guarding against failure of the human element was nothing new but the difference between the old Great Western outlook and that elsewhere had been to place complete reliance on the observation of the Rules and Regulations and signalmen were trained, he thought, to a higher standard which had not in the past justified the introduction of more than the simplest block controls.

In reply to Mr. Riddle, he thought that with the introduction of the reverse pulse feed, multi-code operation of the long track circuit was feasible whilst still maintaining the standard minimum train shunt.

In reply to Mr. Mott, the track circuits were extremely reliable whether of the coded or pulse type and no more maintenance was required than in the case of a conventional steady energy track circuit.

On train describers, the cost of a storage type would have been prohibitive in the case described. It had definitely been much cheaper to overhaul the simple describer and adapt it than to purchase new equipment. The life of telephone type equipment was long and many years' life remained in the describers they had used.

In reply to Mr. Currey, he said that the following comparison of power taken by the two forms of track circuit would be of interest :—

	Coded T.C.		*Pulsed T.C.*	
	Clear	*Occupied*	*Clear*	*Occupied*
Watts (mean)	2·32	6·62	0·784	0·764

These figures were obtained by bench tests with a ballast resistance of 2 ohms. The higher power taken by the coded track circuit was due to the de-coding equipment which took about 6 watts under track occupied conditions.

In reply to Mr. Smaldon, mechanical plant was standardised at 230 volt before nationalisation and much equipment had been bought before the issue of Specification R.E.C. 3. A further point was that a full range of tools was not available for 50 volt working.

In reply to Mr. Wagenrieder, the Great Western practice, still followed in semaphore areas, is to site the ramp just ahead of lower distant signals. In multiple-aspect areas only is the ramp placed 200-yds. on the approach side.

The **President** moved a very cordial vote of thanks to the Author for his excellent paper, which was carried with enthusiasm.

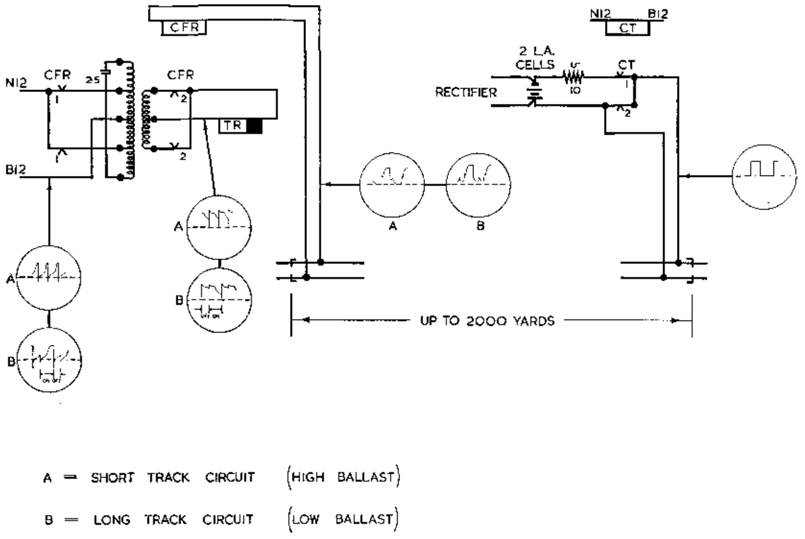

FIG. 1

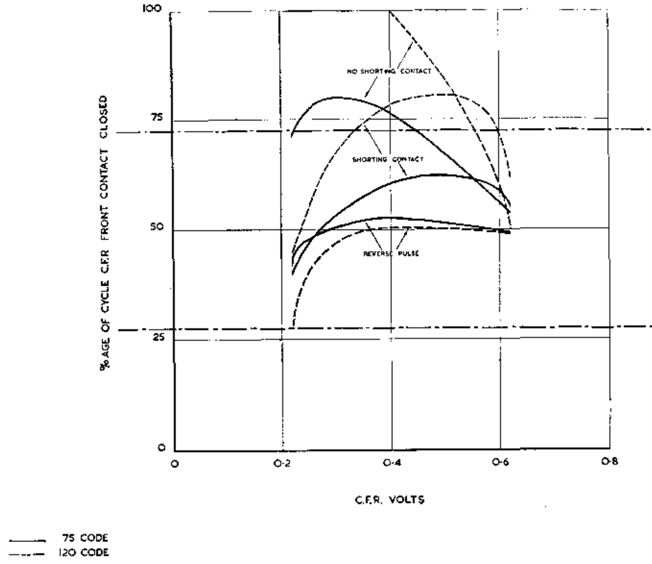

FIG. 3

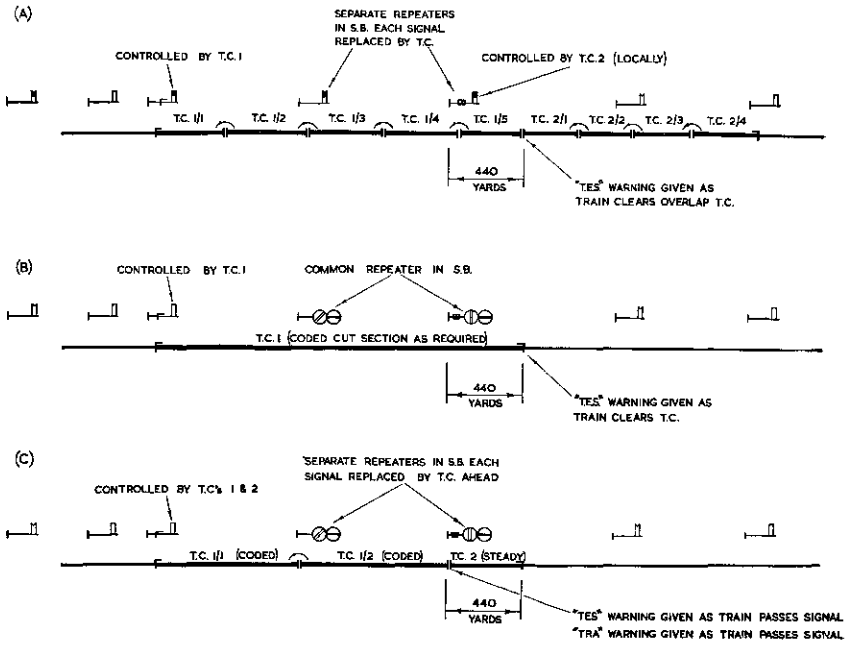

FIG. 5

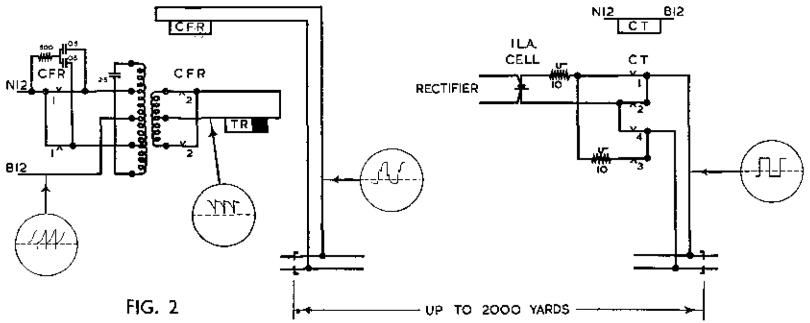

FIG. 2

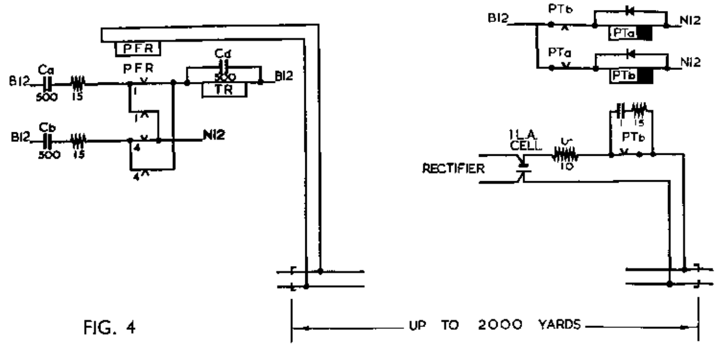

FIG. 4

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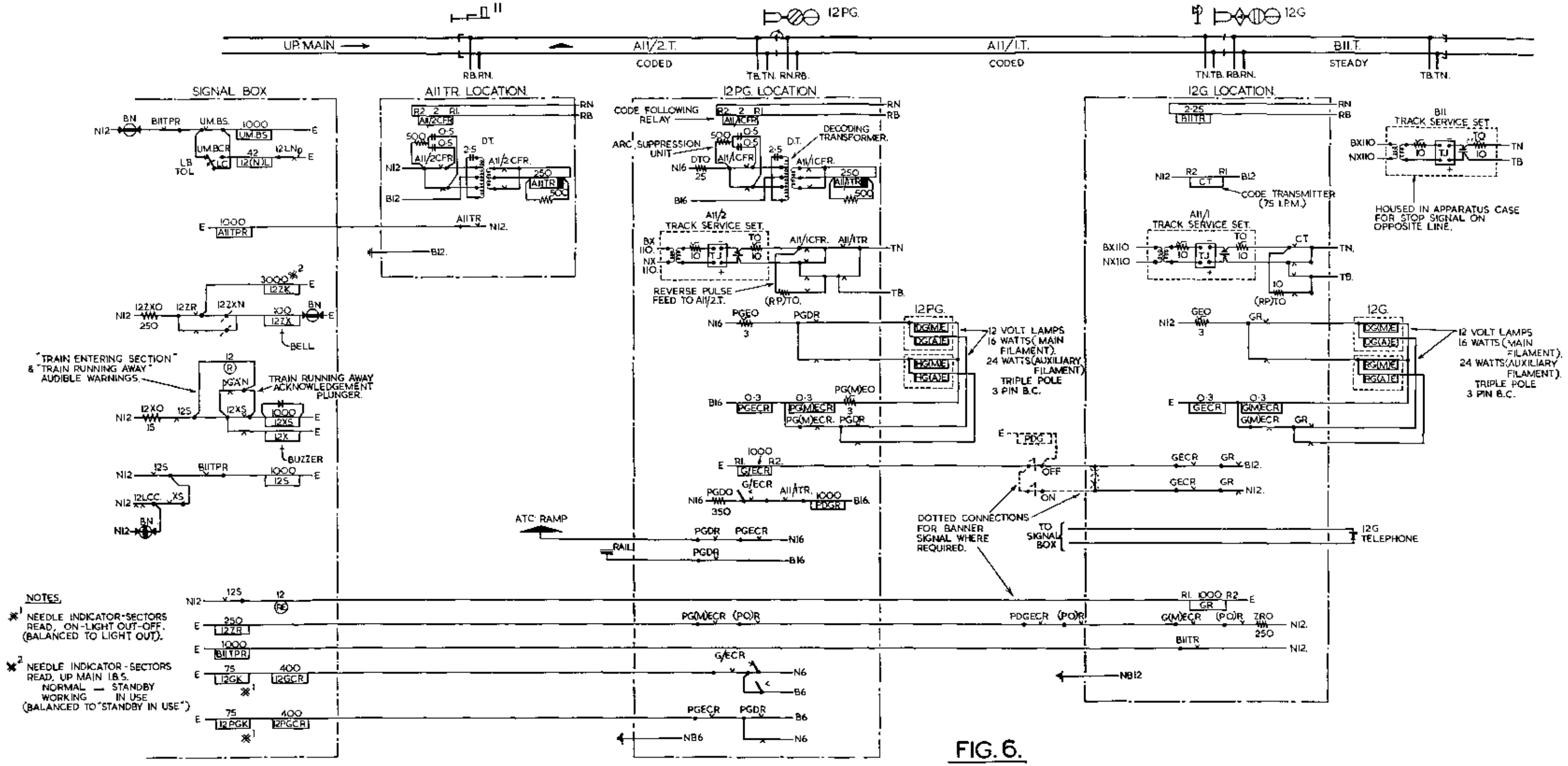


FIG. 6.

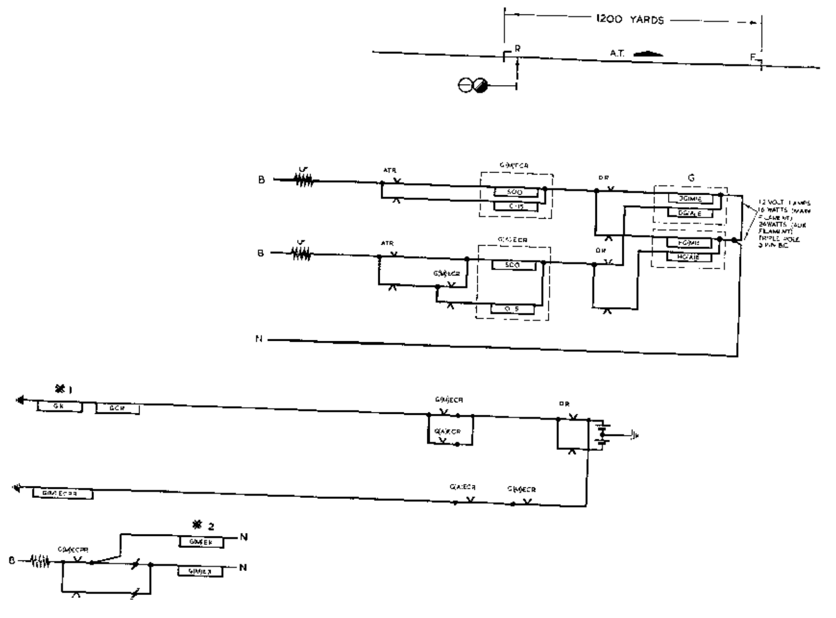
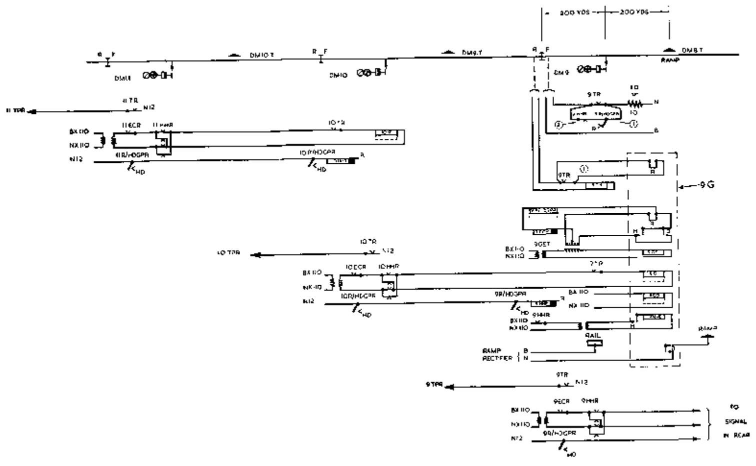


FIG. 7

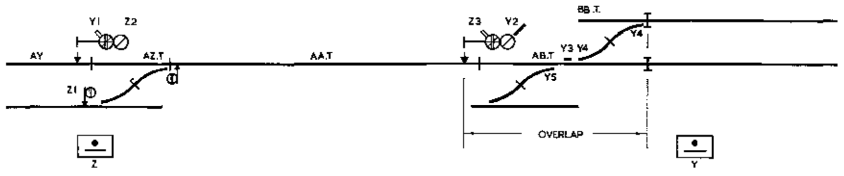


NOTES

① PREVENTS SIGNAL IN REAR CLEARING IF MECHANISM STICKS IN OFF POSITION.

② PREVENTS SIGNAL IN REAR CLEARING MOMENTARILY TO GREEN IF IF REAR TRACK CIRCUIT CLEARS BEFORE HHR RELEASES.

FIG. 8



INDICATIONS

TRACKS :— AY. AZ. AA. [AB. (BB.wY4R) OR Y5a.]

SIGNALS :— Z2 (RED/OFF)

SLOTS :— Z3 (RED/SLOT OFF) Y1 (SLOT ON/SLOT OFF)

CONTROLS

SIGNAL Z1 :— FREE OF TRACK CIRCUIT CONTROL

SIGNAL Z2 :— REQUIRES AZ. AA. [AB. (BB.wY4R) AND Y5N OR AYocc (ATR)]

INDICATIONS

TRACKS :— SPECIAL APPROACH INDICATION. AZ/AA. AB. ETC.

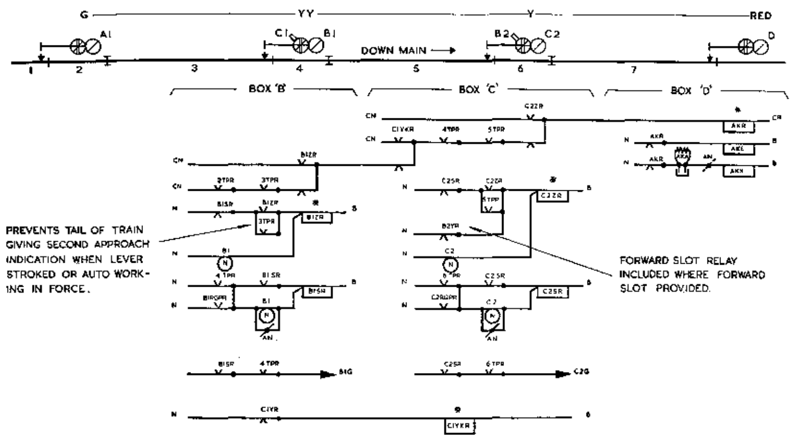
SIGNALS :— Y2 (RED/OFF)

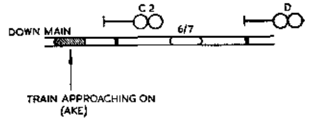
SLOTS :— Y1 (SLOT ON/SLOT OFF)
Z3 (SLOT ON/SLOT OFF)

CONTROLS

SLOT Y1 :— REQUIRES Y3 REV LOCKS Y5 [NON RECIP.]

FIG. 9





BOX 'D' ILLUMINATED DIAGRAM

✱ P.O. 3000 TELEPHONE TYPE RELAYS.

FIG. 10

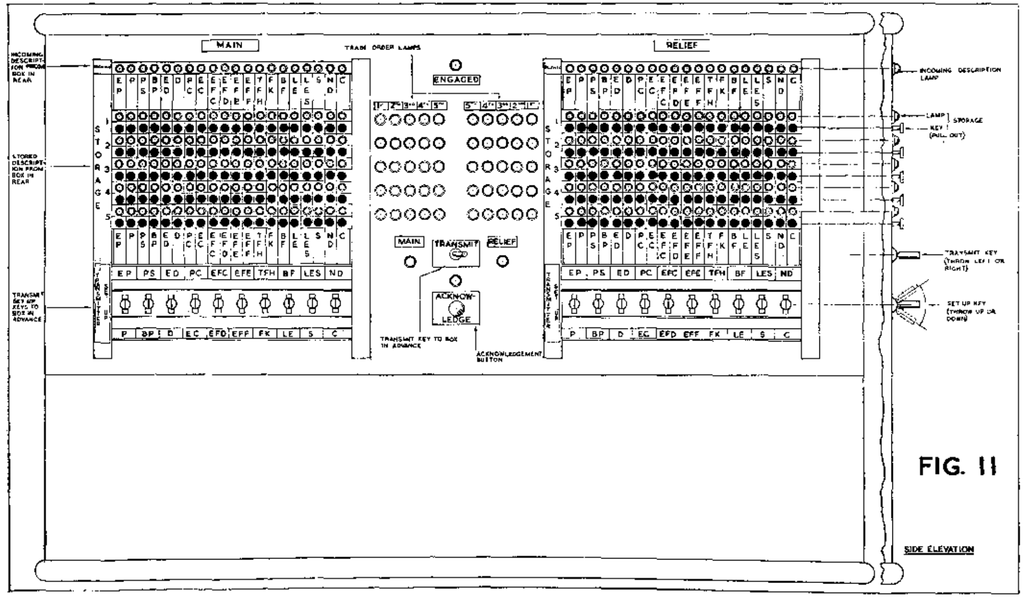


FIG. 11

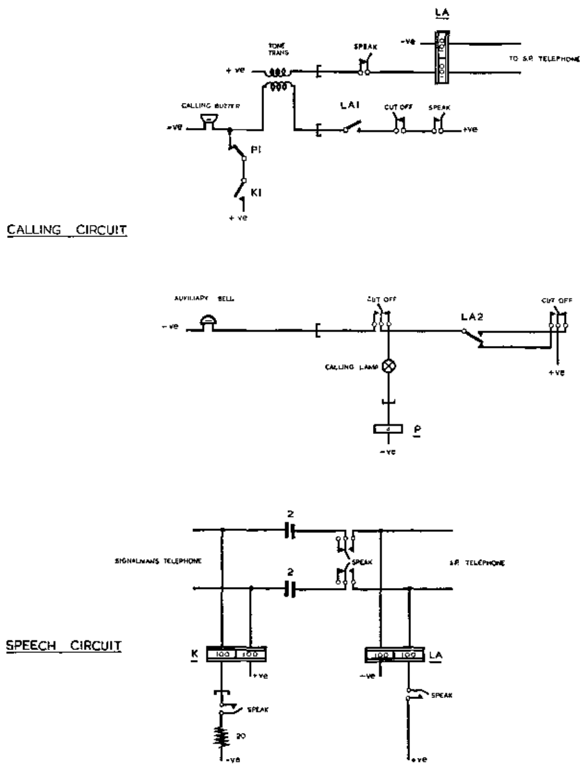


FIG. 12

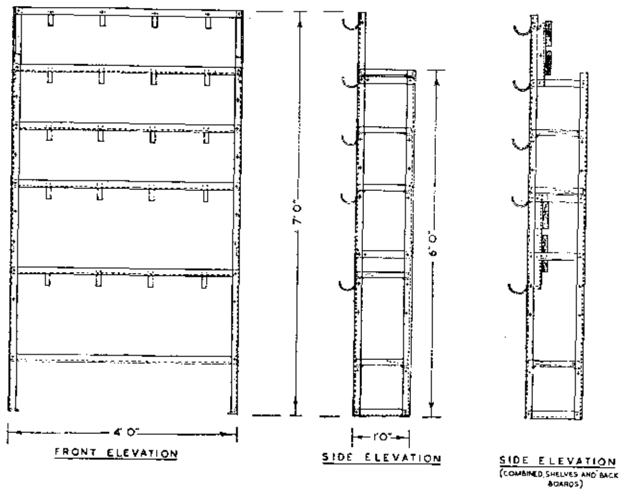
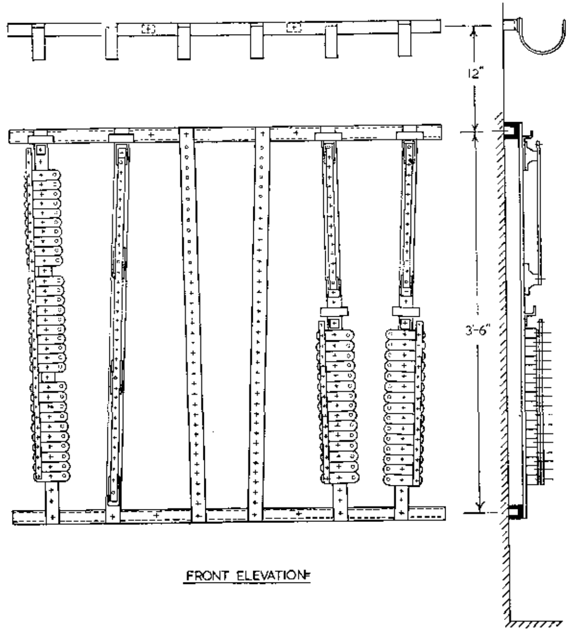


FIG. 13


12"
3'-6"
FRONT ELEVATION

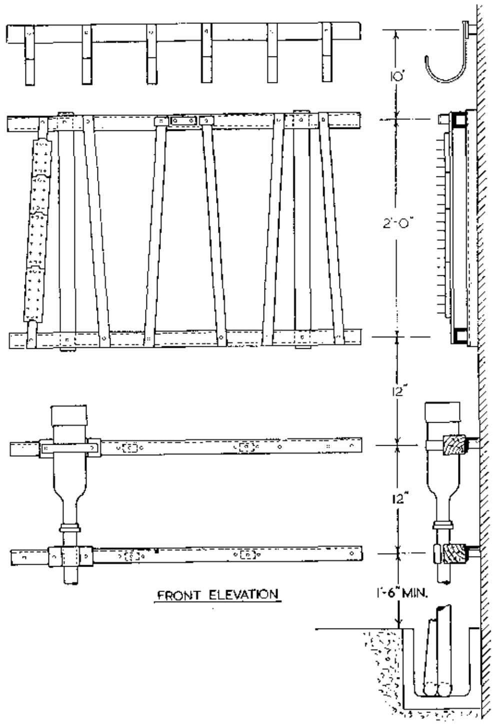
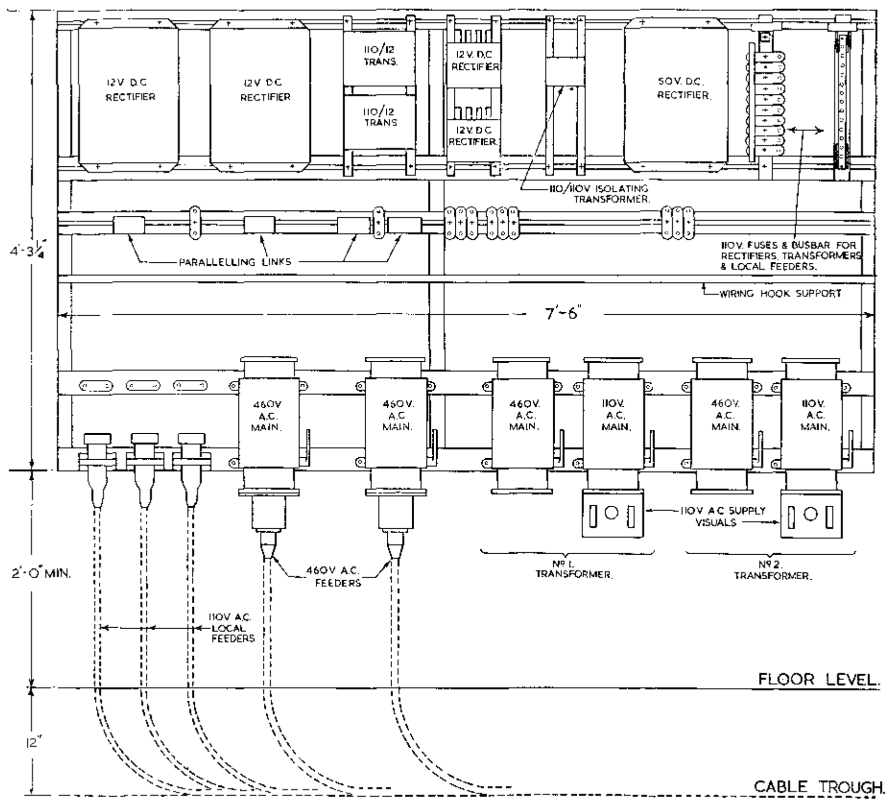

10"
2'-0"
12"
12"
1'-6" MIN.
FRONT ELEVATION

FIG.14.


12V. D.C. RECTIFIER
12V. D.C. RECTIFIER
110/12 TRANS.
110/12 TRANS.
12V. D.C. RECTIFIER
12V. D.C. RECTIFIER
50V. D.C. RECTIFIER
110/110V ISOLATING TRANSFORMER
PARALLELLING LINKS
110V. FUSES & BUSBAR FOR RECTIFIERS, TRANSFORMERS & LOCAL FEEDERS.
WIRING HOOK SUPPORT
4'-3¾"
7'-6"
460V A.C. MAIN.
460V. A.C. MAIN.
460V. A.C. MAIN.
110V. A.C. MAIN.
460V. A.C. MAIN.
110V. A.C. MAIN.
110V A.C. SUPPLY VISUALS
No. 1. TRANSFORMER.
No. 2. TRANSFORMER.
460V A.C. FEEDERS
110V A.C. LOCAL FEEDERS
2'-0" MIN.
FLOOR LEVEL.
12"
CABLE TROUGH.

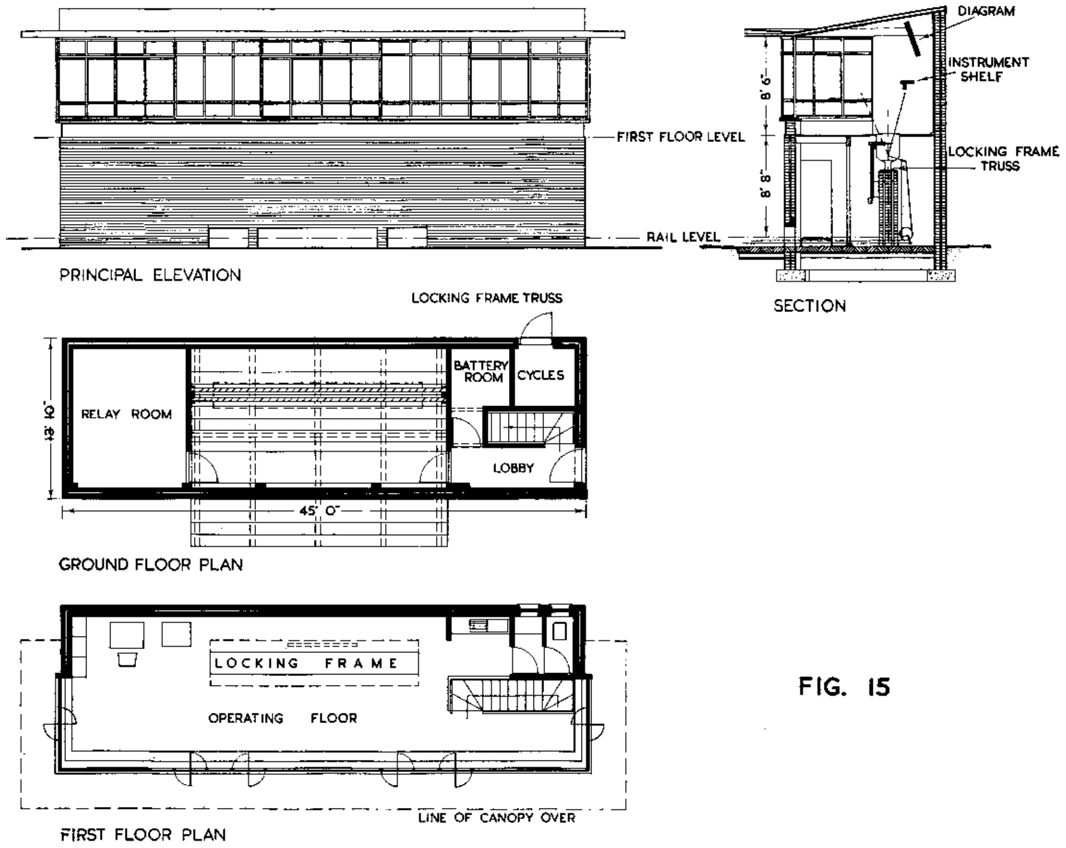


DIAGRAM
INSTRUMENT SHELF
FIRST FLOOR LEVEL
LOCKING FRAME TRUSS
RAIL LEVEL
8' 6"
8' 8"
PRINCIPAL ELEVATION
SECTION
LOCKING FRAME TRUSS
RELAY ROOM
BATTERY ROOM
CYCLES
LOBBY
13' 10"
45' 0"
GROUND FLOOR PLAN
LOCKING FRAME
OPERATING FLOOR
FIRST FLOOR PLAN
LINE OF CANOPY OVER

FIG. 15

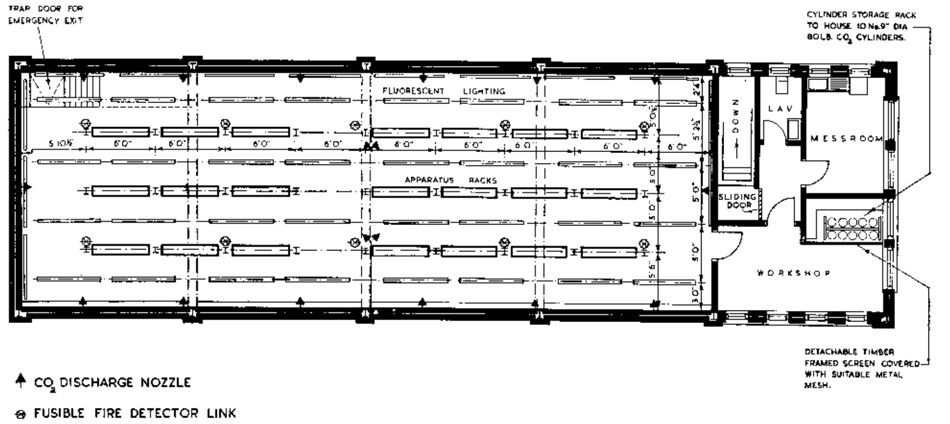

TRAP DOOR FOR EMERGENCY EXIT
CYLINDER STORAGE RACK TO HOUSE 10 No 9" DIA 80LB CO2 CYLINDERS
FLUORESCENT LIGHTING
APPARATUS RACKS
DOWN
LAV
MESSROOM
SLIDING DOOR
WORKSHOP
DETACHABLE TIMBER FRAMED SCREEN COVERED WITH SUITABLE METAL MESH.
CO2 DISCHARGE NOZZLE
FUSIBLE FIRE DETECTOR LINK

FIG. 16