Technical Meeting of the Institution

held at

The Institution of Electrical Engineers

Wednesday, November 16th, 1966

The President (Mr. R. DELL) in the chair.

The Minutes of the Technical Meeting held on 12th October, 1966, were read and approved.

The President introduced and welcomed to the meeting G. C. Pearse (Associate) and G. R. Foster, J. E. Tye, R. Ross and R. J. Fenton (Students) who were present for the first time since their election to membership.

The President also welcomed Mr. D. H. Constable of the Rhodesian Railways.

The President then invited Mr. V. H. Smith (London Transport) to read his paper entitled " Victoria Line Signalling Principles."

Victoria Line Signalling Principles

*By V. H. SMITH**

1. INTRODUCTION

The construction of the Victoria Line is now well in hand and will be the first complete new Tube Line to be constructed in London for more than 50 years. The line will run from Victoria through Central London to Walthamstow in the north-east, and will be a self-contained railway, although connections will be provided with the existing Piccadilly Line at Finsbury Park. These connections will permit the transfer of rolling stock to and from the Chief Mechanical Engineer's Works at Acton and the operation of works trains to and from the line after traffic hours. Fig. 1 shows a map of north-east London, with the Victoria Line Route superimposed and fig. 2 a single-line diagram of the railway, showing interchange facilities with other London Transport Lines and British Railways. It is intended that the line shall be provided with as many automatic features as possible so that the minimum staff will be required for operation. Careful consideration has been given to all modern developments to see if they can be used with advantage in operating this new line. From this consideration the decision has been made to use automatic trains and, in consequence, the signalling of this railway has been designed for their operation. The automatically driven train has other advantages besides economy in staff ; one of which is the facility to enable close headway working to be maintained safely in station areas. In fact, the signalling of the Victoria Line has been designed on a basis of an 82-sec. headway.

**London Transport Board*

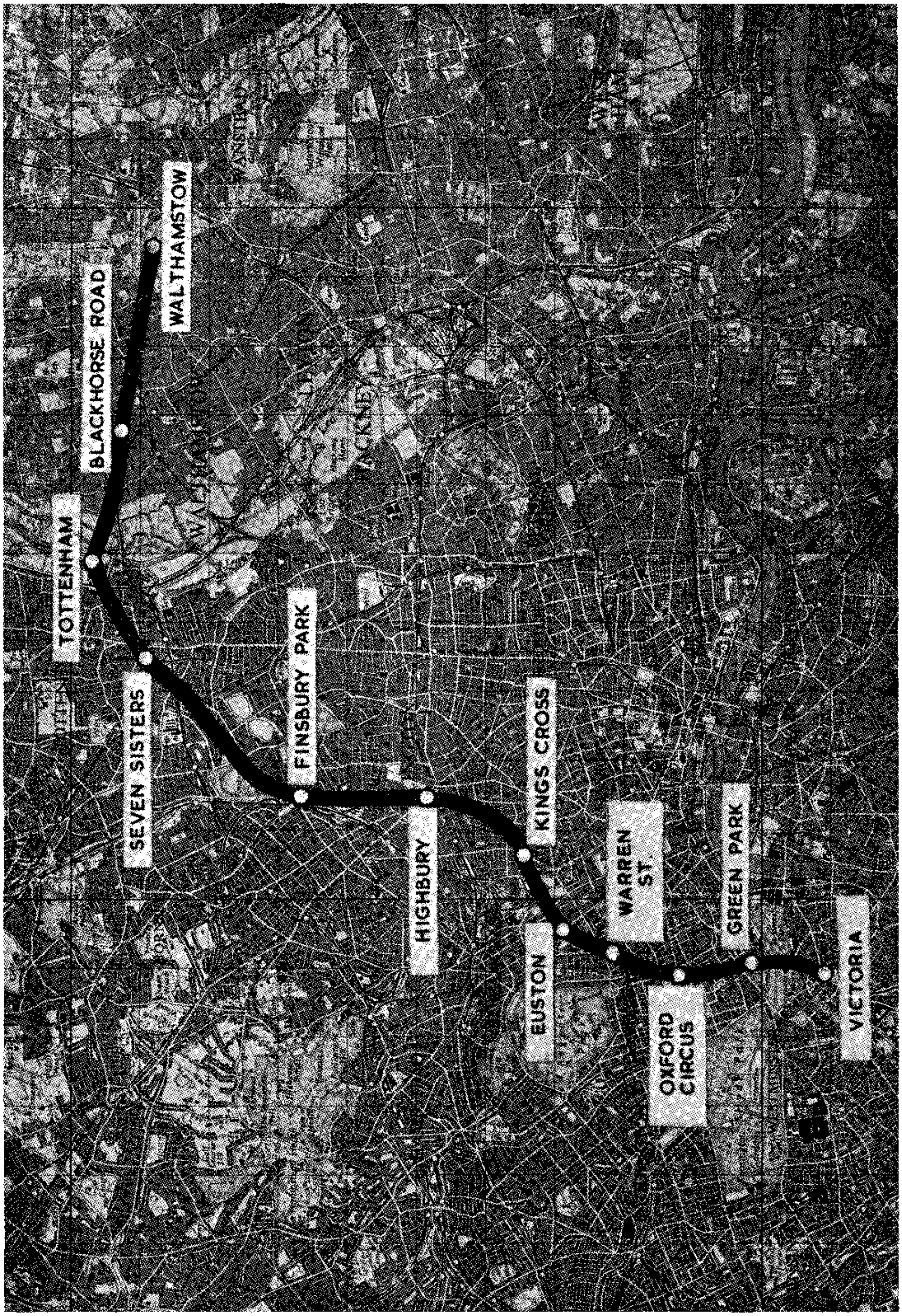

Fig. 1. Route of the Victoria Line.

2. AUTOMATIC TRAINS

The automatic trains will be similar to those used on the Hainault/Woodford Loop trial installation which was brought into public service in April, 1964. A description of the system employed for the control of these trains was given in a paper read before this Institution by Messrs. G. R. Kent and H. Duckitt in March, 1965 and published in the Institution's 1964/5 Proceedings. Since the introduction of the trial service between Hainault and Woodford, it has been found necessary to make certain minor alterations, and the opportunity has also been taken to eliminate the relays in the train carried equipment, by replacing them with solid state circuits. However, the Victoria Line trains will operate on the same principles as the trial installation.

The system of automatic train control is essentially a dual one comprising the safety system and the train command system. For the train to proceed under automatic working it must be receiving code from the track. The code is applied to the running rails by interrupting the track circuit feed and is detected on the train by coils mounted immediately above the rails preceding the leading wheels of the train. The train apparatus will respond only to codes of 180, 270 and 420 pulses per minute. The 180 and 270 codes permit the train to run at 22 m.p.h., the 180 code not permitting the train to motor, whilst the 270 code has no such restriction. The 420 code permits the train to run at maximum speed. A 120 code is also introduced into the track circuit, but this is for signalling purposes only and is not detected on the train. If no code is received by the train, or the train speed exceeds 22 m.p.h. whilst receiving 180 or 270 code, the emergency brakes are automatically applied and the train brought to rest. It should be observed that this system is designed on a 'fail safe' basis.

The train command system is used to stop trains at signals and in platforms, and to introduce coasting at appropriate parts of the Line. These commands are conveyed to the train by "Spots" positioned along the Line as appropriate. These "Spots" are essentially audio-frequency generators, the outputs of which are fed into short lengths of one running rail. The coils on the train detect the generated signal when they pass over the "Spot" and the train responds accordingly. A 20 KC signal gives instruction for the train to stop if the signal ahead is at danger, whilst a 15 KC signal gives

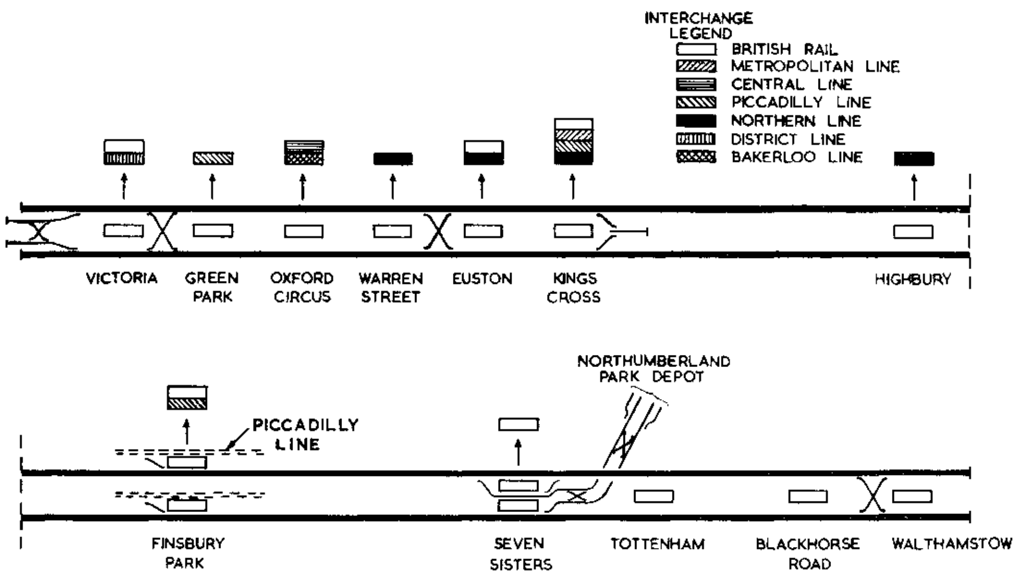

Fig. 2. Single Line Diagram of Victoria Line.

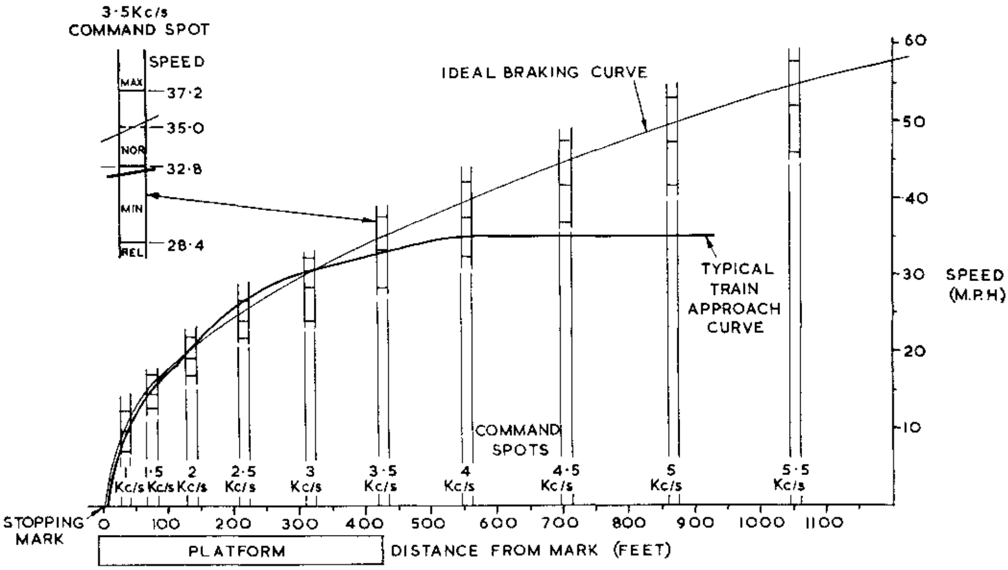

Fig. 3. Braking Curve Showing Train Response to Command Spots.

instruction for the motors to be cut off and the train to coast. The spot generators used to effect the stopping of trains at stations denote different speeds and for convenience their frequencies are to the scale 1 m.p.h. = 100 cycles per second, thus, a 1 KC spot equals 10 m.p.h.

Station spots are positioned approaching, and in the station area, at points where a train should be at the corresponding speed if following the ideal braking curve. If the train speed is in excess of the spot value, the brakes are applied harder whilst, if the train speed is lower than that of the command spot, the brakes are released. This system, which is illustrated in fig 3, enables a stopping accuracy of plus or minus 5-ft. to be achieved in platforms.

In case of emergency, such as failure of equipment, facilities are provided on the automatic train for the train operator to drive the train. The train circuits are so arranged that providing the train is still receiving code from the track, it may be driven at a speed not exceeding 22 m.p.h. Should this speed be exceeded, the emergency brakes are automatically applied and the train brought to rest. If no code is being received by the train, the operator is restricted to a speed of 10 m.p.h. and likewise, if this speed is exceeded, the emergency brake is automatically applied.

3. RELATIONSHIP OF OVERLAPS TO SIGNALS

On London Transport the overlap provided at a signal is always calculated for the maximum speed which a train achieves at the signal position. This calculation is based on an emergency braking rate of 10 per cent. of gravity on open sections and 12 per cent. in tunnel sections. The result is also adjusted for gradient ; the overlap being reduced if the gradient is up and increased if down. A 30 per cent. safety factor is also included in the calculations. Hitherto the overlap being calculated on this basis has ensured that the train will come to rest within that overlap should the emergency brake application be made by the train striking the trainstop. On the Victoria Line no trainstops will be provided, but the same overlap calculation will be used to determine the overlap length required. In the event of a train inadvertently entering an overlap when the section ahead is occupied, the train will be stopped by the application of the emergency brake due to the loss of code received on the train. With conventional signals it has always been necessary to position the signal an overlap distance from the point that the signal protects. This has meant that, particularly in the case where high speeds are met, the signal is a considerable distance from the fouling point. With automatic trains, it is possible to get the train much nearer the fouling point without lessening safety standards. It is, in fact, this feature that enables a train to approach closer to an occupied platform, thus reducing the headway between trains.

As an automatic train approaches a signal it will encounter a 20 KC spot which will be energised if the signal is at danger. This spot will be so positioned that the brake application caused by the train passing over it at full speed will bring the train to rest using the service braking rate at the signal. At some point, which can be determined from the braking curve, between the 20 KC spot and the signal, the train will be travelling at 22 m.p.h., and it is at this point that the overlap for maximum train speed commences. Any train passing this point in excess of 22 m.p.h. must be automatically brought to a stand by the emergency application of its brakes. To meet this condition, the track circuit from the start of the overlap to the signal must be fed at 180 code if the signal is at danger. The signal itself will be provided with an overlap calculated for a train speed of 25 m.p.h. This arrangement provides absolute safety, because if a train should pass the critical point at a speed in excess of 22 m.p.h., there is an adequate overlap for the maximum train speed possible. Should the train over-run the signal at the maximum speed of 22 m.p.h. that it can approach, there is a 25 m.p.h. overlap to provide the requisite safety margin.

Should the train be driven manually, its speed is governed to a maximum of 22 m.p.h. ; the signal with its 25 m.p.h. overlap still provides absolute safety. The arrangements for conventional and automatic train working are shown in the diagrams, Fig. 4, below.

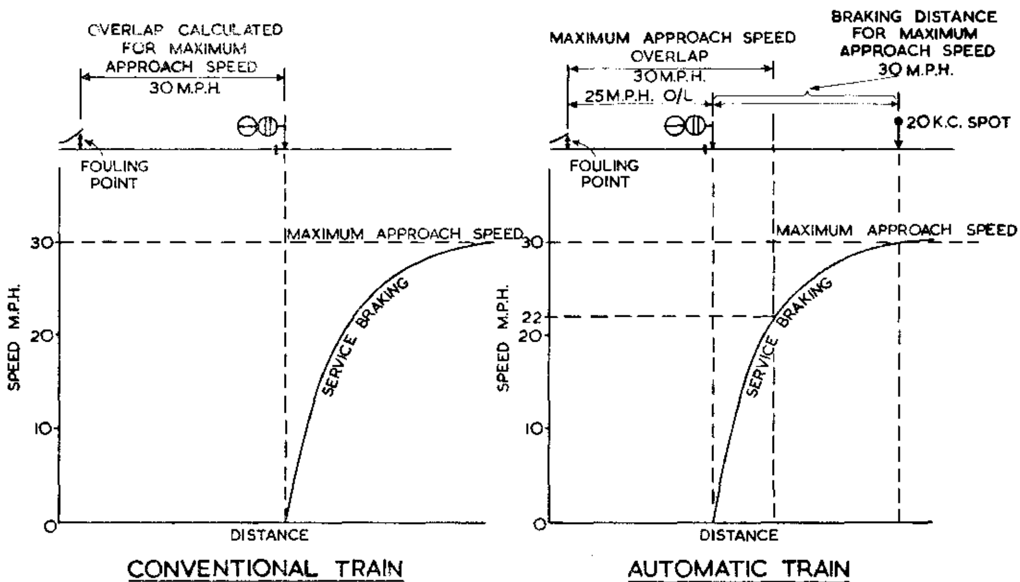

Fig. 4. Relationship of Overlaps to Signals.

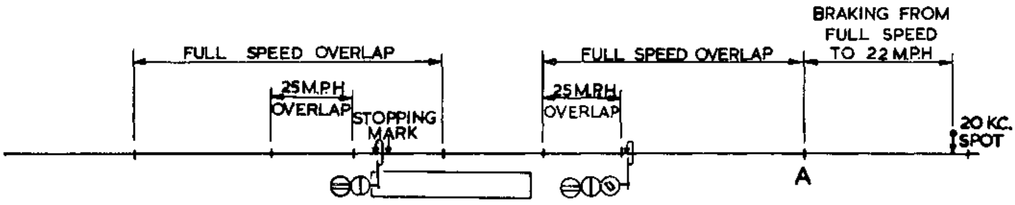

Fig. 5. Relationship of Overlaps to Signals in Station Area.

4. SIGNALLING IN AREAS WHERE THERE ARE NO JUNCTIONS OR CROSSINGS

For the normal operation of automatic trains lineside signals are not required, but, under emergency conditions, when the train operator has to manually drive the train, they are desirable. This facility is being provided in limited form. Lineside signals are being installed at starting, intermediate and outer-home signal positions only. The home signal is positioned at 25 m.p.h. overlap distance in rear of the station.

If the section is clear, the automatically-driven train will proceed towards the station at full speed, being brought to rest in the station by the influence of the station braking command spots. If, however, the station is occupied the approaching train will receive a brake application due to the 20 KC spot in rear of the home signal being energised. This command spot is positioned so that the train will have reduced speed from the maximum possible for the section concerned, to 22 m.p.h. at the point " A ", shown on fig. 5. This point " A " is full speed overlap distance from the station and is, of course, the position where the conventional home signal would normally be installed. If the home signal is at danger and the train speed is not less than 22 m.p.h. when it reaches this point, it will be tripped and come to rest within the full speed overlap, thus avoiding collision with the train ahead. If the train speed is below 22 m.p.h., as would be the usual case, the train will continue to brake and stop at the home signal.

As the preceding train starts to move out of the station, it will clear each of the 25 m.p.h. moving overlaps shown in fig. 6. Directly the first of the 25 m.p.h. moving overlaps is cleared by the preceding train, the following train will be permitted to move towards the station at a speed not exceeding 22 m.p.h. The outgoing train is then protected by the first of the 25 m.p.h. moving overlaps.

As the outgoing train continues to accelerate, it will clear in succession each of the 25 m.p.h. moving overlaps each overlap in turn providing the protection for the train, and at the same time permitting the incoming train to proceed into the platform.

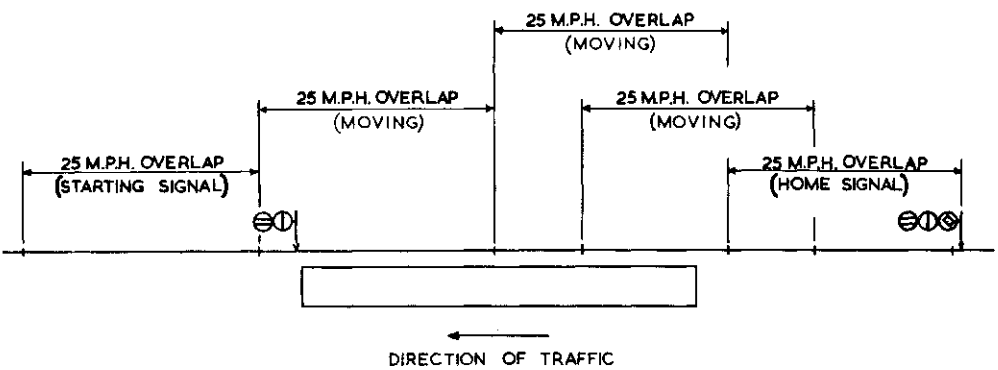

Fig. 6. 25 M.P.H. Moving Overlaps.

A full speed overlap is also provided for the starting signal commencing in the rear of the signal in a similar fashion to that for the home signal.

5. HEADWAY

The close headway working, using moving overlaps, is only suitable for the automatically driven train, as no inner home signals are being provided. The emergency manually-driven train must wait at the home signal until the preceding train has cleared the overlap of the starting signal. The circuits have therefore been so arranged that the home signal will not show a green light until the section is clear right up to the end of the overlap of the starting signal. To avoid the automatically-driven train passing a red light, the red light at the home signal will be extinguished directly the outgoing train has cleared the first 25 m.p.h. moving overlap, and a banner aspect at the home signal will be illuminated.

Fig. 7 shows a time distance curve for a typical station area. This diagram shows the previous train departing from the station with normal acceleration, and the following train running in at the controlled speed of 22 m.p.h. On all headway calculations on London Transport, a 30 sec. station stop is assumed and, as can be seen from the diagram, under these conditions the following train can depart 82 sec. after the preceding one. Beneath the time distance curve, the track diagram has been repeated several times and on each, the relative position of the two trains, together with the protecting overlap, has been indicated. Absolute safety is achieved with this arrangement, as should anything untoward happen to the outgoing train and it comes to rest unexpectedly, there is always a protecting 25 m.p.h. overlap in rear in which the incoming train, the speed of which is restricted to 22 m.p.h. under this mode of operation, will be automatically tripped.

As already stated, the clearing of the home signal under automatic operation for full speed running will not take place

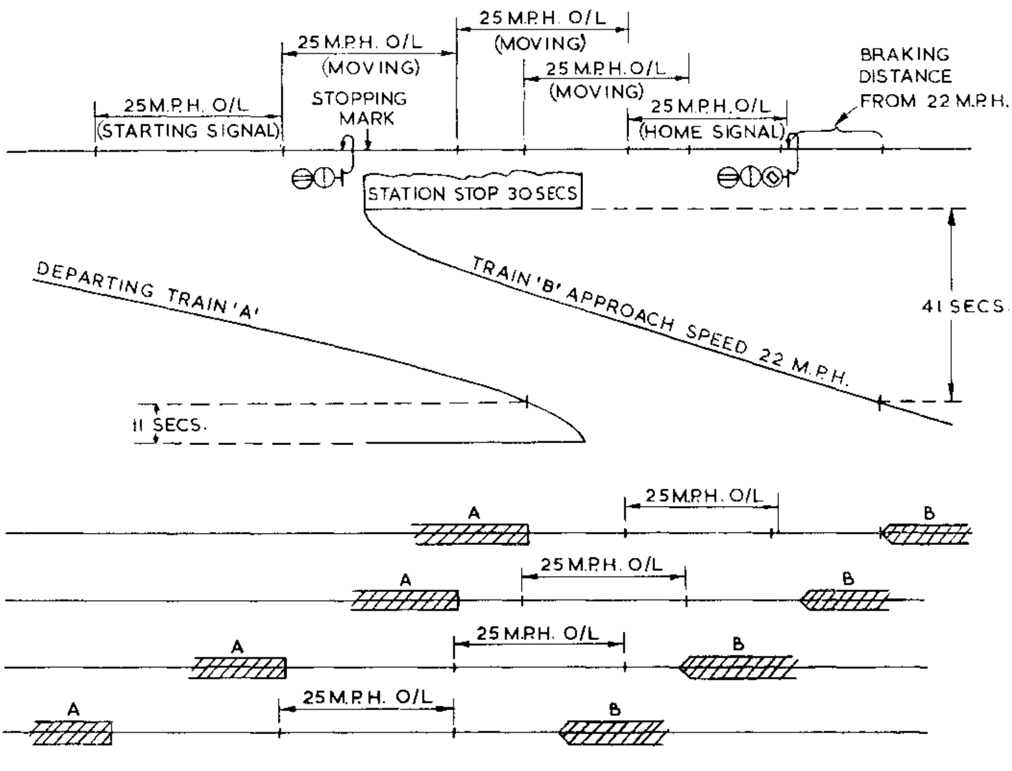

Fig. 7. Station Home Area Time Distance Curve.

until the preceding train has cleared the starter signal overlap. With such an arrangement, this should, of course, be the end of the full speed overlap of the starting signal but this is very restrictive, and under certain conditions would unnecessarily delay the following train. If the incoming train is not permitted to run at full speed until the home signal has cleared, which would be when the previous train has cleared overlap of the starting signal, the incoming train is subjected to a considerable distance of 22 m.p.h. operation. This, of course, causes loss of running time which would reflect back on the train service. In order that the home signal may clear earlier, thus making 22 m.p.h. running unnecessary if the incoming train arrives on the approach of the home signal when the outgoing train is already accelerating away from the station, full speed moving overlaps are provided. These full speed overlaps provide protection to the outgoing train in a similar fashion to the 25 m.p.h. moving overlap. The arrangement adopted is shown in fig. 8. This diagram also shows a time distance curve for a train approaching as the previous train is leaving the station, plotted for the conditions with and without the full speed moving overlaps. It can be seen from these two curves that the moving overlaps provide a saving of 25 sec. running time.

6. SAFETY CIRCUITS

Fig. 9 shows a typical coded track circuit. The track feed set is essentially an electronic switch which interrupts the track circuit feed in correspondence to the pulses of its control circuit. The control circuit is switched to the 120, 180, 270 or 420 code bus bars as circumstances dictate. The relay set passes a feed to the track relay provided the pulses it is receiving from the track circuit are at a rate of 120 to 420 pulses per minute. If the track circuit is shunted by the presence of a train, no pulses reach the relay set and in consequence the track relay is de-energised.

The circuit and use of the relay 603B C.S.R. is designed to prevent 420 code appearing on track circuit 603B if a train has passed the 20 KC spot when it was energised. This is necessary because when an automatic train approaches the home signal which is at danger, it will receive a stop command from the 20 KC spot This causes the train brakes to be applied and the train to come to rest at the signal. The stop command is only countermanded by the train receiving 270 code from the track, which occurs when the

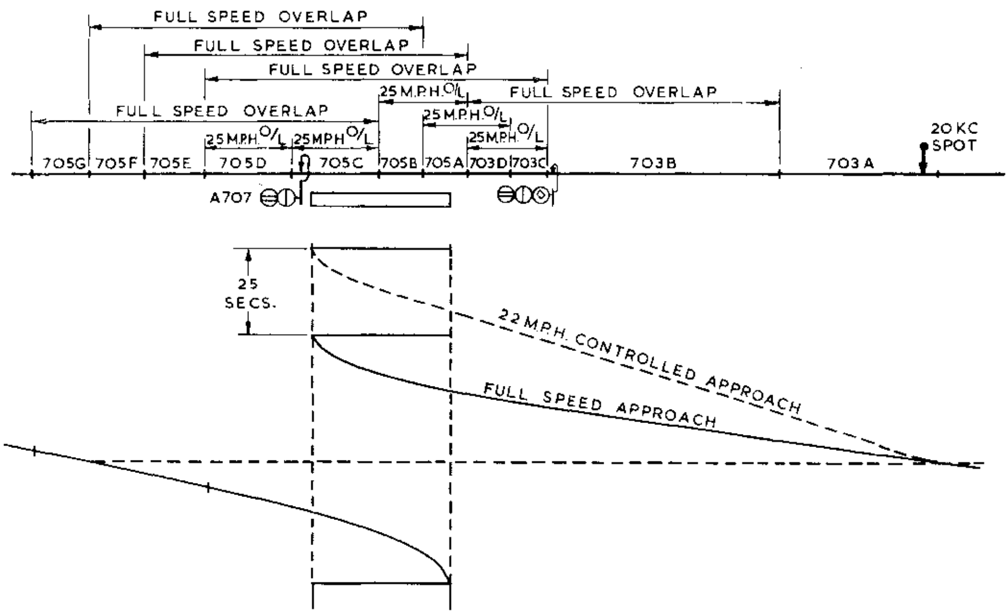

Fig. 8. Full Speed Moving Overlaps Time Distance Curve.

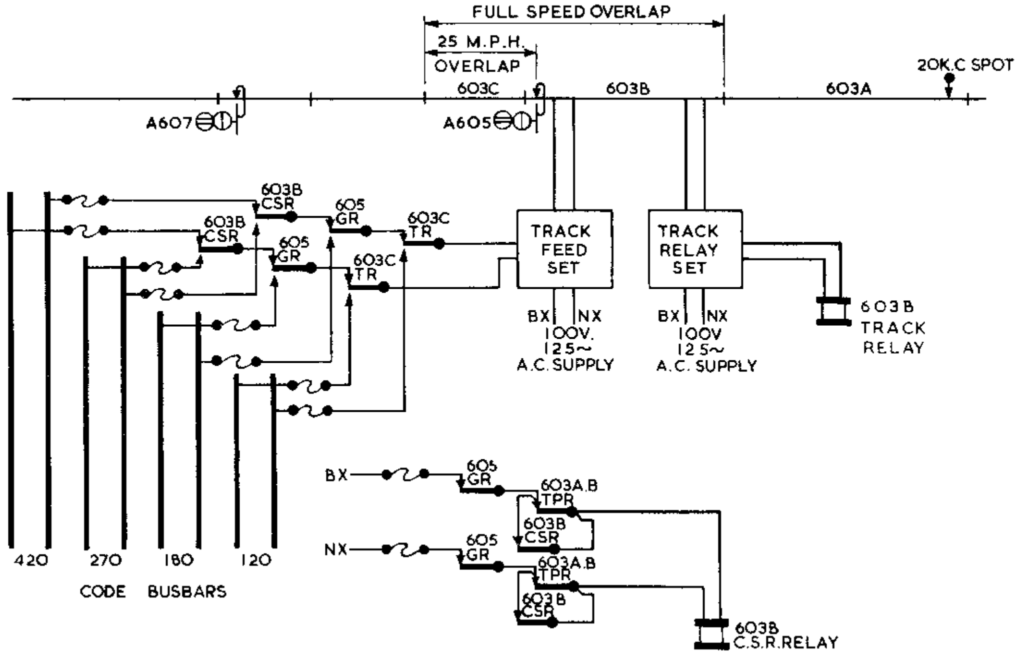

Fig. 9. Typical Coded Track Circuit.

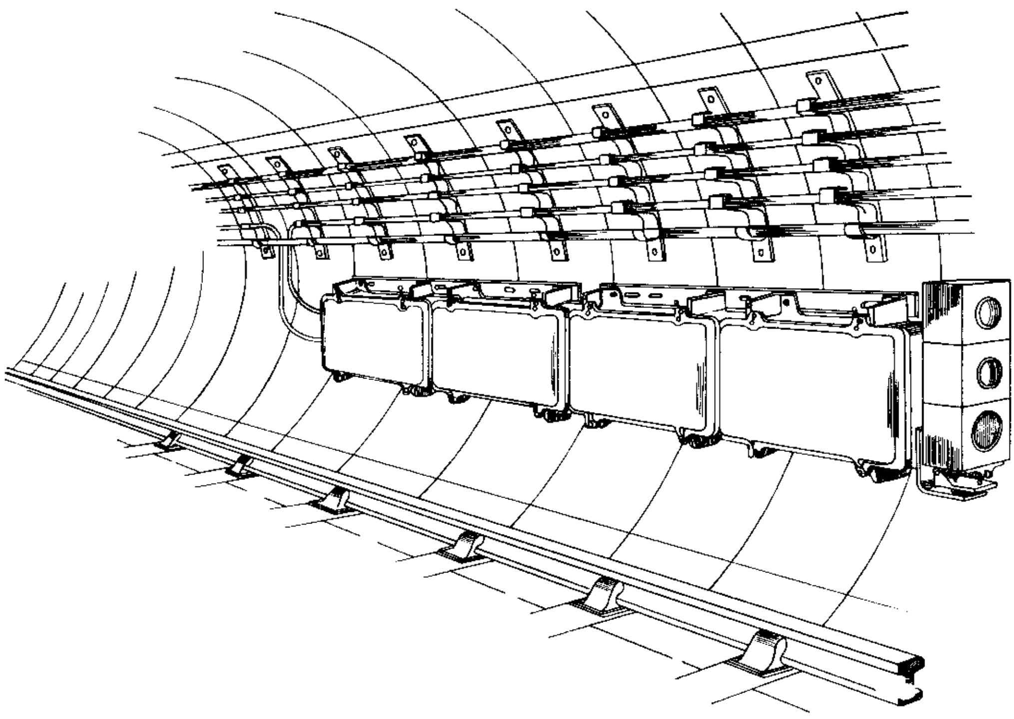

Fig. 10. Signal Location Victoria Line.

signal clears. Consequently it is essential to ensure that the train receives 270 code and this is achieved by the C.S.R. circuit, which prevents 603B track changing from 180 to 420 without the 270 code being applied if a train is approaching.

The C.S.R. relay must be energised for 420 code to be applied to 603B track circuit and this relay is de-energised when the signal is at danger and the 20 KC spot energised, and prevented from picking up when the signal clears if the next train has occupied track circuit 603A.

On the Victoria Line, all signalling apparatus as far as possible will be housed in relay rooms situated at either end of the platforms. This ideal is not practicable in the case of intermediate signals situated between stations which are a considerable distance apart. For such situations a special tunnel location case has been developed to house all the required signal apparatus together with the signal at one end. These units will be pre-wired so that on site it is only necessary to connect the appropriate cable connections. A pictorial drawing is shown in fig. 10.

The signal circuit shown in fig. 11 is based on relay room wiring and is for a typical station home signal. The banner signal relay is controlled by all track circuits up to and including the first 25 m.p.h. moving overlap, whilst the colour light signal is controlled up to the end of the first full speed moving overlap.

With automatic train operation, the track circuit code selection circuits are the most important feature of the installations. Fig. 12 shows these circuits required for a station area. The control circuits are double cut as shown in fig. 9, but the NX circuits, which are identical to the BX circuits, have been omitted to simplify the diagram.

These track coding circuits are best explained by a reference to the schedule contained in fig. 13. This schedule indicates the codes which are required for each track circuit and the conditions which must be satisfied before that code is applied to the track. In principle, each track circuit will be coded at 420 pulses per minute permitting full speed working when all track circuits up to the end of the full speed overlap ahead are clear. If this condition is not satisfied, but track circuits up to the end of a 25 m.p.h.

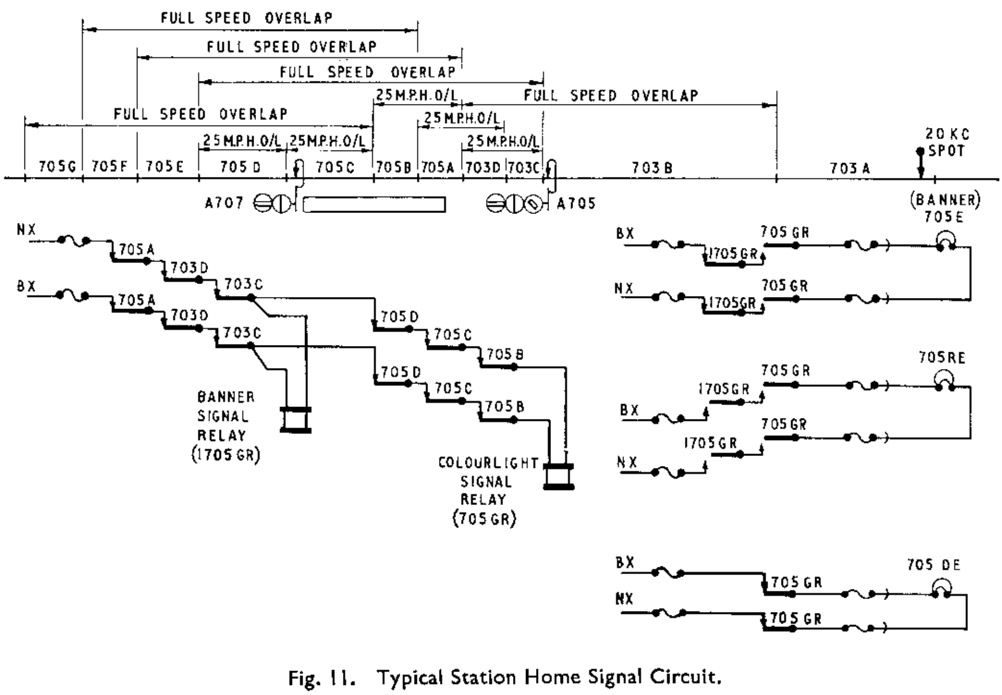

Fig. 11. Typical Station Home Signal Circuit.

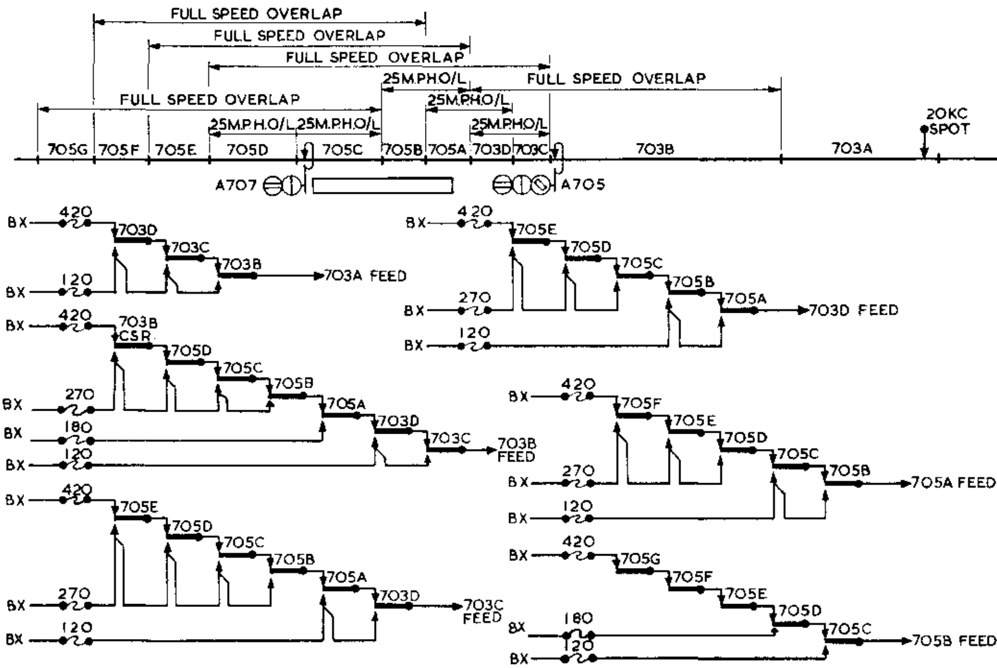

Fig. 12. Track Code Circuits for Station Area.

overlap ahead are clear, then the track will be coded at 270 pulses per minute, and if neither of these conditions are satisfied, then a code of 120 pulses per minute is applied. The circuits are so arranged that only one code is applied at a time; the highest rate permissible taking precedence.

Track circuit 703B can also operate at 180 code. The code is selected when signal 705 and its banner are at danger and will prevent an approaching train tripping providing its speed is less than 22 m.p.h. This is necessary as the receipt of 270 code on the train cancels the brake instruction which obviously cannot be given until the banner signal clears.

Once the incoming train passes the home signal under automatic working, it will do so under the protection of either the full speed or the 25 m.p.h. moving overlaps. No lineside signals or indications will be given to the train operator. However, it is not anticipated that, under normal circumstances, the incoming train tion receive an emergency brake applica- will because it has entered a protecting overlap, because it is expected that the outgoing train, which is accelerating, will clear the overlaps ahead of the incoming train which, of course, is slowing for the station stop. Absolute safety is maintained for, should the outgoing train come to rest, then the incoming train will be stopped within the protecting overlap.

7. SIGNALLING IN INTERLOCKING AREAS

At junctions and crossings an interlocking machine room will be provided housing the conventional London Transport form of interlocking machine. This machine will be used to control the protecting signals in the same way as for conventional trains.

The shafts of the interlocking machine will be allocated to individual signals and points and crossovers. These shafts will be mechanically interlocked and provided with approach lock and back lock facilities and, in fact, fitted with every safety device as provided on all London Transport installations. The track code circuits will also contain, where appropriate, contacts of the interlocking machine shaft and the point detection. Fig. 14 shows track

TRACK CIRCUIT	TRACKS CLEAR FOR 420 CODE	TRACKS CLEAR FOR 270 CODE	TRACKS CLEAR FOR 180 CODE	CONDITIONS FOR 120 CODE
703^A	703^B, 703^C, 703^D	———	———	IF CONDITIONS IN COLUMN 2 NOT SATISFIED
703^B	703^C, 703^D, 705^A, 705^B, 705^C, 705^D & PROVIDED TRAIN HAS NOT PASSED ENERGISED 20Kc/s SPOT	703^C, 703^D, 705^A	703^D, 703^C	IF CONDITIONS IN COLUMN 2, 3 OR 4 NOT SATISFIED
703^C	703^D, 705^A, 705^B, 705^C, 705^D, 705^E	703^D, 705^A	———	IF CONDITIONS IN COLUMN 2 OR 3 NOT SATISFIED
703^D	705^A, 705^B, 705^C, 705^D, 705^E	705^A, 705^B	———	IF CONDITIONS IN COLUMN 2 OR 3 NOT SATISFIED
705^A	705^B, 705^C, 705^D, 705^E, 705^F	705^B, 705^C	———	IF CONDITIONS IN COLUMN 2 OR 3 NOT SATISFIED
705^B	705^C, 705^D, 705^E, 705^F, 705^G	———	705^C	IF CONDITIONS IN COLUMN 2 OR 3 NOT SATISFIED

Fig. 13. Track Circuit Coding Schedule for Station Area.

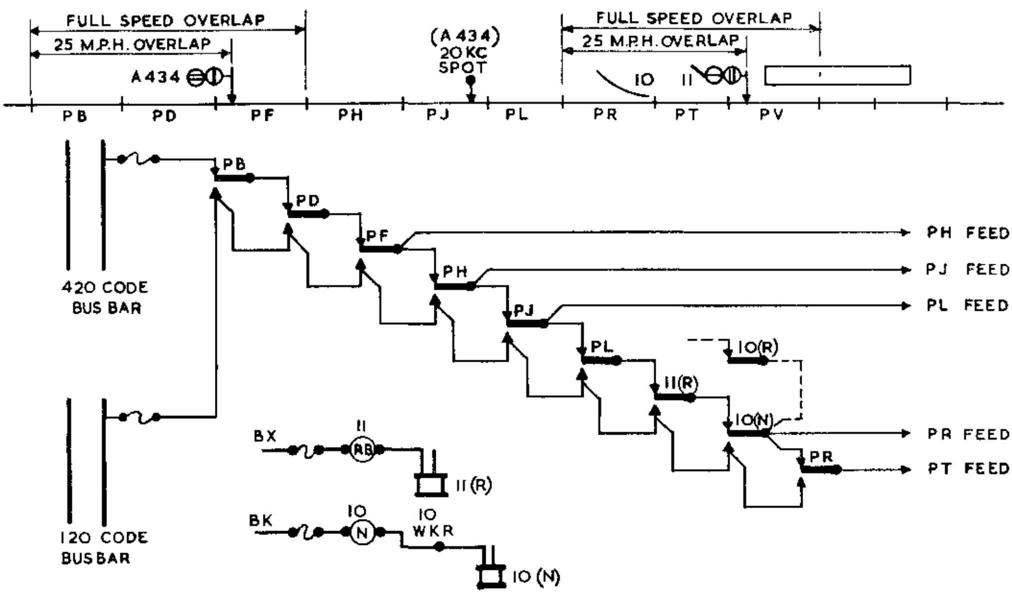

Fig. 14. Track Coding Circuits at a Facing Junction.

coding circuits for use at a facing junction. The track circuits illustrated in this example can either operate on the 420 code or the 120 code, and it should be noted that before any track circuit can operate on the 420 code, the route must be set and clear to the end of the overlap of the signal ahead. This arrangement provides continuous detection of the points which will be effective, even after the train has passed the junction signal as loss of detection will remove the 420 code causing an emergency brake application of the train.

8. PROGRAMME MACHINES

At all interlocking sites programme machines will be provided to route all scheduled train movements automatically. These machines will follow the principles already applied on other lines of London Transport, and described in detail in papers by Messrs. Dell and Woodhouse, read to the Institution and contained in Proceedings for 1958 and 1960.

Opportunity has been taken to modify the circuits so that all programme machine controls are now effected by electronic circuits, thus dispensing with the Post Office type relays used hitherto; but these changes do not affect the facilities provided. The electronic components for these circuits have been incorporated in printed circuit cards. These cards are used in racks and attached to their corresponding terminal block by fourteen 6B.A. screws. These screws form the electrical connection for the circuits and are considered to be more reliable than the conventional plug-in arrangement. The 6B.A. screws are captive, and whilst admitting that it takes slightly longer to change a card than using plug-in connections, the operation can be completed in less than a minute. Fig. 15 shows a facing junction together with a block schematic diagram detailing the conditions that must be satisfied before the left hand route for No. 32 signal can be set up. The conditions referred to in the block schematic relate to automatic working and do not include facility for the supervisor to set the route manually by push button. This has been omitted deliberately to simplify the illustration.

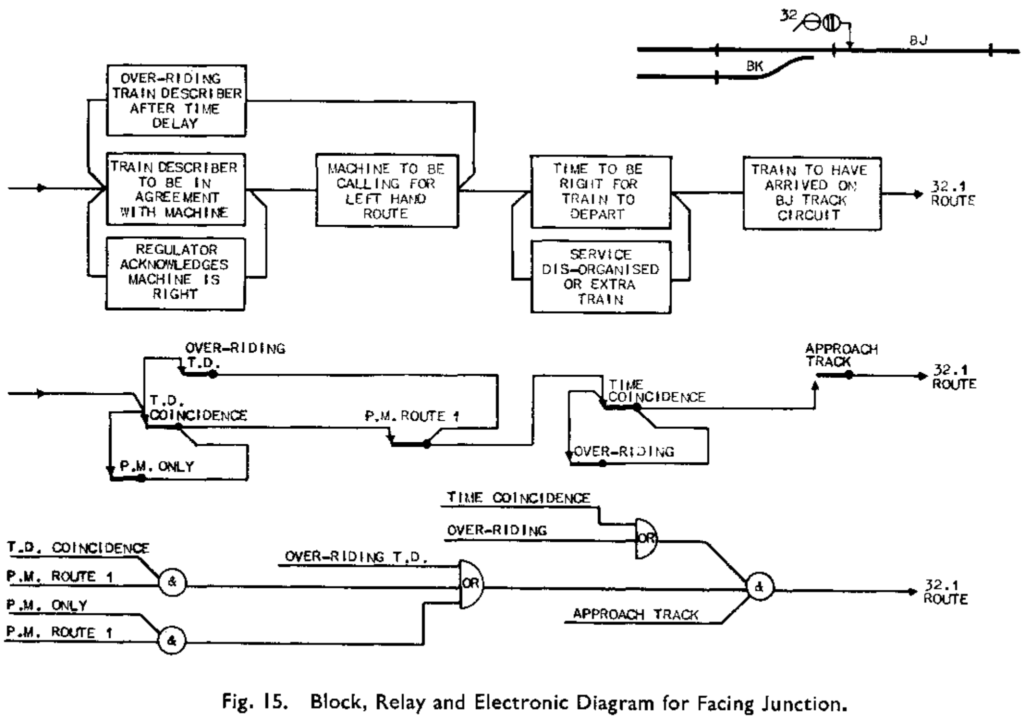

Fig. 15. Block, Relay and Electronic Diagram for Facing Junction.

In considering these conditions it can be seen that first the train describer should be in agreement with the machine; second, the programme machine to be calling for the left hand route; third, the time to be right for the train to depart, and fourth, for the train to have arrived on B.J. track circuit. When these conditions are satisfied a feed is passed forward to operate route 32.1, the left hand route of 32 signal. Alternative arrangements are provided if the train describer and programme machine disagree. If this is the case the regulator is warned by a bell and indicator at the supervision room. If he acknowledges that the programme machine is right, then another path is provided as an alternative to the train describer in agreement condition for the set up of route 32.1. If the regulator does nothing, then after an interval of one minute, the overriding train describer condition will operate and the route will be set by the left hand train describer code. The time function can be by-passed so that the route may be cleared without delay if the train service is disorganised or for the running of extra trains.

Immediately under this block diagram is shown the circuit using relay contacts to produce the conditions required for the control of this route. Where contacts appear in series, these can be said to be "AND" conditions because to meet the requirements both conditions must be satisfied. Where contacts are in parallel, these can be said to be "OR" conditions, for either condition in this case will satisfy the requirement.

Electronic circuits can be constructed for the setting of this route using "AND" and "OR" gates. These gates, as their names imply, will in the case of the "AND" gate only give an output when all input conditions are satisfied and in the case of the "OR" gate will give an output when any one of the input conditions is satisfied. The circuit for setting route 32.1 is shown at the bottom of this diagram using "AND" and "OR" gates.

These gates have been designed to form flexible "bricks" on which the programme machine circuits can be constructed. The illustration given represented only one such application.

Fig. 16 shows the circuit for an "AND" gate. Before a negative can appear at the output terminal the three input terminals must not be positive. If any one of the inputs is positive then the output terminal is positive. This forms a very simple but effective "AND" gate arrangement and two such gates have been constructed on each of the "AND" gate printed circuit cards. Fig. 17 shows the circuit arrangement for an "OR" gate. In this case if a negative is applied to any one of the input terminals negative appears at the output terminal. Experience has shown that if these two simple

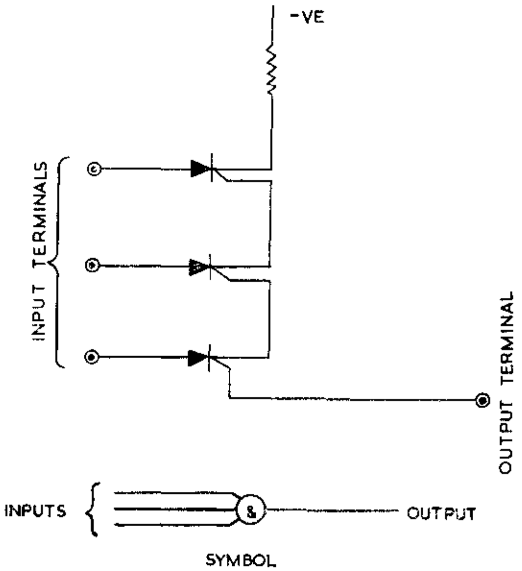

Fig. 16. "AND" Gate Circuit.

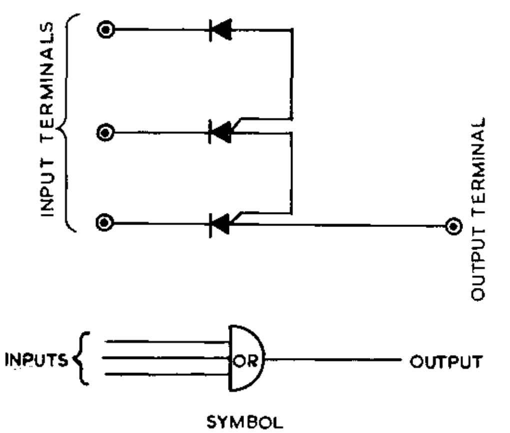

Fig. 17. "OR" Gate Circuit.

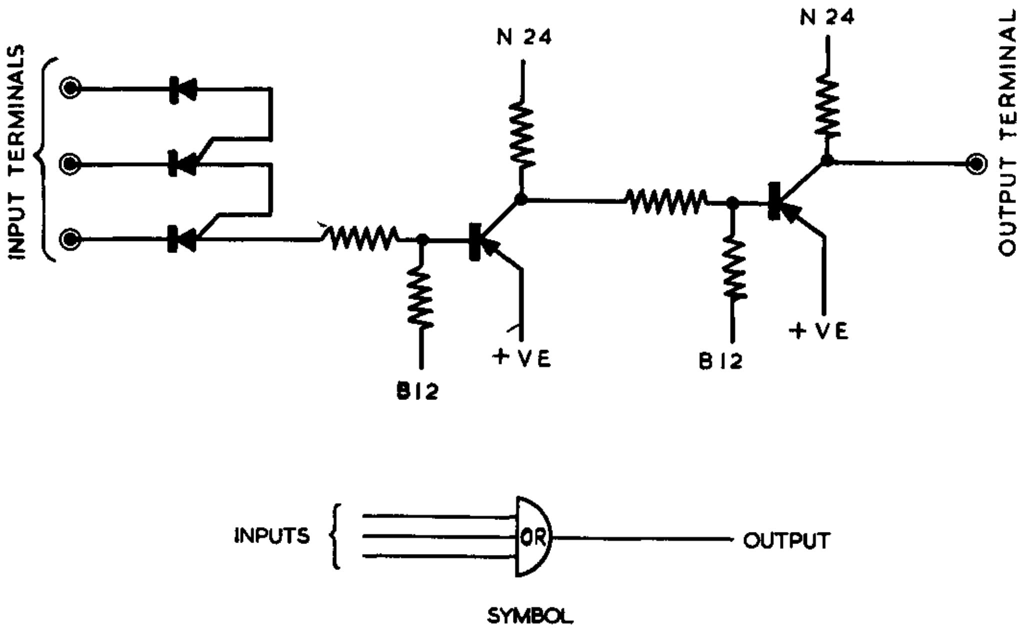

Fig. 18. " OR "Gate Circuit Card.

gate circuits are used it is necessary to include some form of amplification in the network and therefore the " OR " gate has been constructed as described but the diode output has been fed into a two stage amplifier, the two stages being necessary to prevent the signal being inverted. One such " OR " gate together with its amplifier has been constructed per printed circuit card and the circuit is shown in fig. 18. These basic units form the electronic circuits and can be wired in any configuration to achieve the desired effect.

It should be noted that on London Transport these circuits are non-safety circuits and only give an instruction for a route to be set. Before points can be moved or a signal cleared all safety requirements have to be satisfied by the safety circuits, which are separate and additional to these non-safety circuits.

9. REGULATING ROOM—COBOURG STREET

With the provision of programme machines covering all schedule routes, it is theoretically possible for the whole line to work entirely automatically throughout the day for seven days in the week. However, provision has been made for overall supervision to be carried out from a control room at Cobourg Street, near Euston. This room will be similar to the District Line room already built at Earls Court, and will contain an illuminated diagram of the whole of the Victoria Line showing the whereabouts of every train and facilities to enable the Regulator to intervene should something untoward happen. These facilities provide for the running of extra trains, or the cancelling of scheduled trains, or, in emergency, for the programme machines to be cut out and the signalling worked from push buttons. This room will also house the Line Traffic Controller, and in due course have similar facilities for controlling the Northern Line.

10. NORTHUMBERLAND PARK DEPOT

At Northumberland Park a Depot, with stabling sidings for all the trains used on the Victoria Line, and facilities for the Chief Mechanical Engineer's Department to service trains is being constructed. This depot will also contain two washing machines for the exterior washing of the trains. The control of shunting movements within the depot will be in the hands of a shunter who will be housed in a control tower overlooking the whole of the depot. He will operate from a control desk, which will have facilities for the remote setting of all points and contain track circuit indications showing the whereabouts of every train in the depot. No signals will be provided, but facilities will be installed to enable the shunter to speak to and receive messages from the train drivers, either by carrier wave system using the current rails or by talk-back loudspeakers strategically placed about the depot. The actual method of communication has not yet been decided upon, and in fact is dependent upon results of experiments now in hand. Instructions relating to train movements will be passed by this communication system.

A number of red lights, having wide angle beams which can be seen from all parts of the depot, are to be provided for emergency use. The lights when switched on by the shunter, are to be an instruction for all train movements to stop. This is intended as an emergency facility should the shunter believe that his last instruction has been misunderstood. Fig. 19 shows the layout at Northumberland Park, and is in fact a picture of the control panel.

At the entrance to the depot are two reception roads, where trains are placed by the shunter when they are due to enter service. From here a waiting train will be signalled away to Seven Sisters by the programme machines in the interlocking machine room at Northumberland Park. Likewise, when a train is to come out of service the programme machine will route the train to the appropriate reception road, whence the shunter takes over and directs the train to the desired stabling road.

The shunter's control tower circuits are all electronic. In fact, the only contacts are on the point control thumb switches, and these contacts are of the hermetically sealed reed type. The contacts are contained in a sealed tube, and are operated magnetically by a permanent magnet rotated by the knob so that the magnet comes into close proximity of the reed contact as the switch is turned. The track circuits are entirely electronic, having no relays. The units provide indication to the shunter of the occupancy of the track circuit, and also provide track locking for the points so that the shunter cannot move the points if they are occupied by a train. The points are operated electro-pneumatically and comprise a drive cylinder, a detector box and a spring toggle device to keep them in the position last thrown. No locks are fitted. The point detector box has no contacts, it being actuated as a proximity detector.

With the exception of the track circuits on the reception roads, the depot track circuits are required only for indication purposes, or a form of track locking where points are situated within that track circuit's limits. Fig. 20 shows the wiring for a track circuit. The feed end is conventional, being a resistance fed track

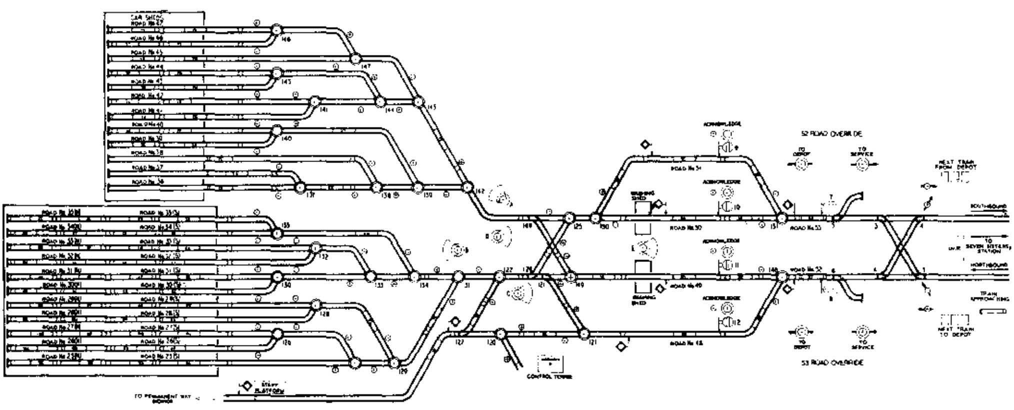

Fig. 19. Northumberland Park Depot.

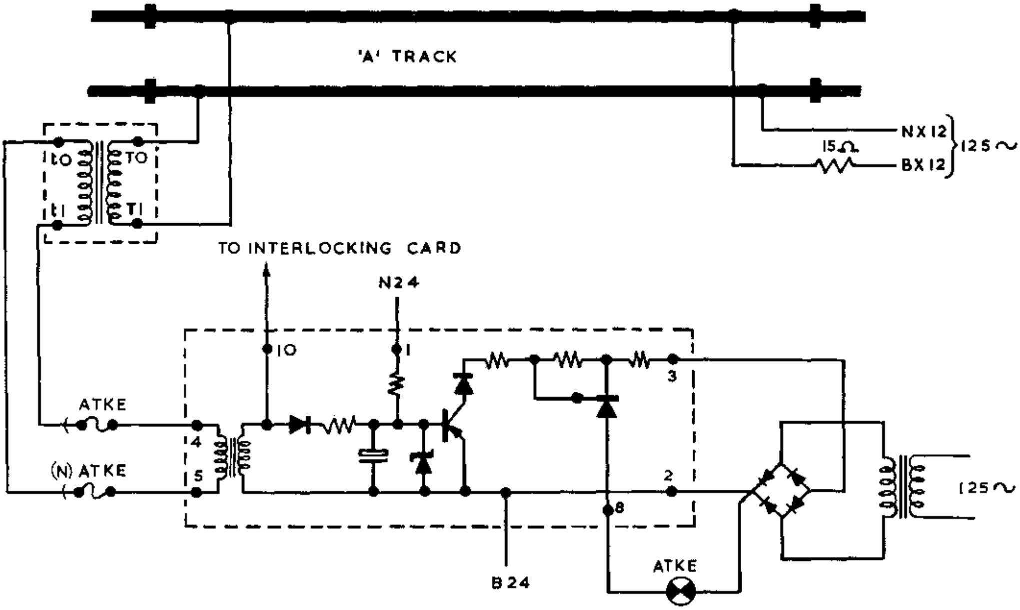

Fig. 20. Wiring for a Track Circuit.

circuit; but the " relay " end comprises a transformer situated outside, adjacent to the track circuit. The secondary of this transformer feeds, via cable, to the relay room, into an electronic printed circuit card. When an A.C. signal of approximately 30 volts is applied to the input terminals of this card, the resulting D.C. positive counteracts the permanent negative feed to the base of the transistor, switching the transistor off. With the track circuit shunted no such A.C. signal is available and the permanent negative feed to the base of the transistor then causes the transistor to switch on. In the ON condition, that is when the track is shunted, a positive is fed to the gate of the silicon controlled rectifier or thyristor, causing it to conduct. The voltage applied to the indication circuit is unsmoothed D.C. derived from a transformer rectifier set, so that when the thyristor is switched on unsmoothed D.C. current flows through the indication lamps and

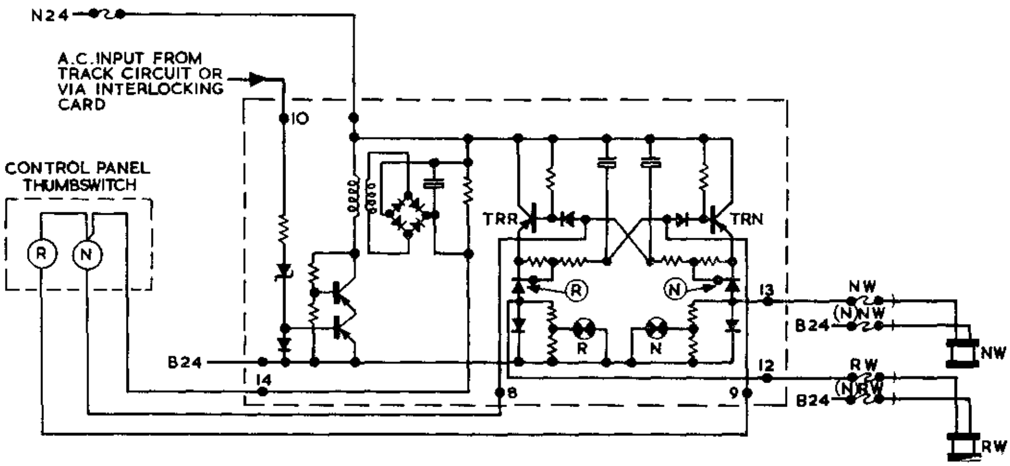

Fig. 21. Point Control and Printed Circuit Card.

the thyristor which are connected in series. When the gate of the thyristor is switched off the main circuit of the thyristor will switch off directly the current is zero, and this will occur within a half a cycle because of the use of unsmoothed D.C.

By this arrangement the track circuit indication lamps are illuminated when the track circuit is occupied, and extinguished when the track circuit is clear. Each printed circuit card has been designed to cater for two track circuits.

The point control circuit, which is also electronic and arranged on a printed circuit card, is shown in fig. 21. The points are controlled electro-pneumatically, and the normal and reverse valves are connected to the relay room by cable terminating on the N.W. and R.W. fuses. The point control circuit is basically a toggle circuit using two thyristors designed to correspond to the position of the panel thumb switch and to remain where last set, should the thumb switch be moved when the track locking track circuits are occupied. The operation of this circuit can best be explained by considering the points to be normal, and following the sequence as they are thrown to the reverse position. With the point thumb switch normal, the normal thyristor is fired, the circuit being maintained through transistor T.R.N. whose base is made negative via the resistor connected to the negative bus bar. With the thyristor fired, a negative appears at terminal 13, and in consequence a feed is supplied to the normal valves. Before the points can be reversed an A.C. signal must be applied to terminal No. 10. This signal will be amplified and cause A.C. to appear on the transformer of the transformer rectifier set. Under these conditions the transformer rectifier set will give a positive to terminal 14, and moving the thumb switch to the reverse position will apply this positive to terminal 9 and remove it from terminal 8. This positive will counteract the negative applied to the base of transistor T.R.N. thereby switching it off and cutting off the normal thyristor. The positive on terminal 9 will also fire the reverse thyristor. This circuit will be maintained through the transistor T.R.R. which will now assume the "switch on" position due to the removal of the positive from terminal 8 by the movement

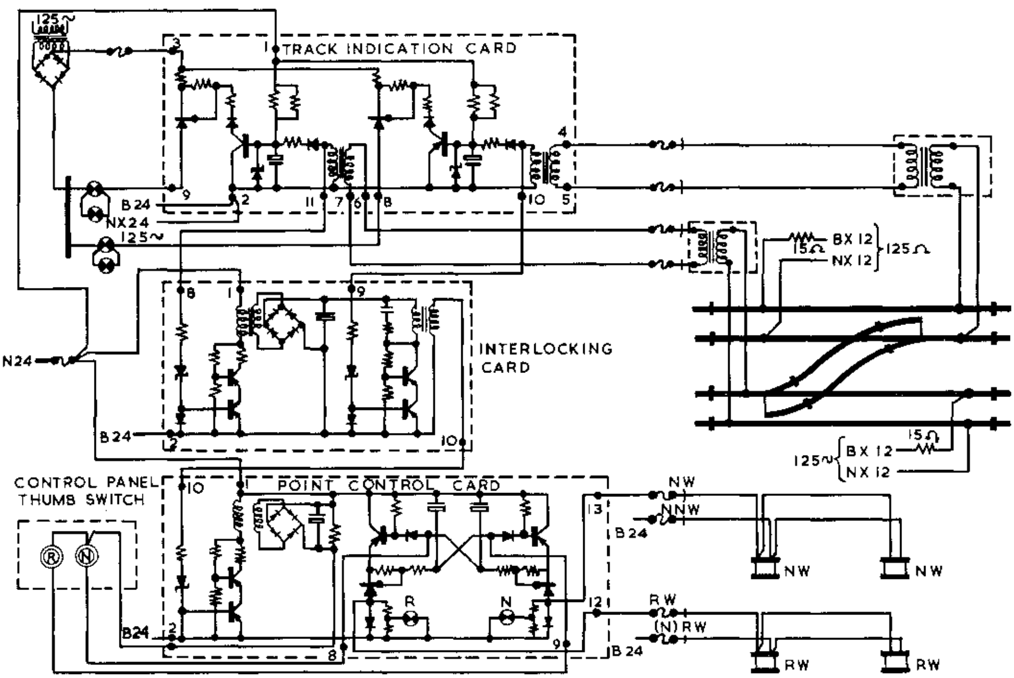

Fig. 22. Circuit for Crossover.

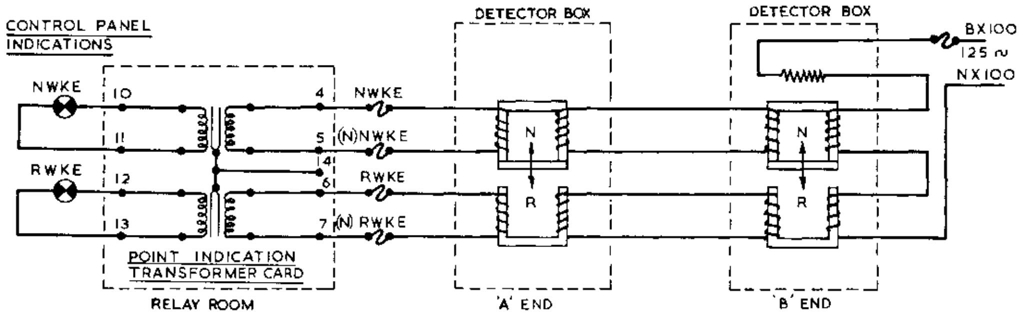

Fig. 23. Point Detection Circuit for a Crossover.

of the control panel thumb switch. The cutting off of the normal thyristor will remove the feed from the normal valves and the firing of the reverse thyrister will operate the reverse valves. To restore the points to normal the A.C. signal must again be fed to terminal 10, the circuit functioning in a similar way.

The A.C. signal on terminal 10 of the point control card is derived from the track locking track circuits clear. If more than one track circuit is concerned an interlocking card is used. The object of this feature is to prevent the points being moved if the track circuits are occupied by a train. A typical arrangement for two track circuits, an interlocking card and a point control card for a crossover is shown in fig. 22. The interlocking card will only supply an A.C. output at its terminal 10, which is in turn connected to the point control card terminal 10, when it is receiving an A.C. signal from both track circuits,—one being fed into terminal 8, the other into terminal 9. The A.C. received on terminal 8 is amplified and rectified to form the D.C. for the amplifier for the A.C. signal on terminal 9. Therefore if A.C. is not present on either of these two input terminals no A.C. will appear at the output terminal 10.

The point detector is contact-less, a special form of proximity detector being used for this purpose. The circuit is shown in fig. 23, which shows the arrangement for a double-ended crossover. Each end of the crossover is fitted with a detector box, in which an iron core moves in relation to the point switches. When the points are in the normal position, the iron core completes the iron circuit of the normal coil and in the reverse position it completes the iron circuit of the reverse coil. With the core in contact with the coil unit transformer action can take place between the two windings and a voltage appears at the indication lamp causing it to be illuminated. Fig. 24 shows a graph of the voltage on the indication lamp relating to the movement of the core away from the coil unit. From this graph it can be seen that the lamp is completely extinguished with a movement of approximately 0.020 in. The iron core is provided with adjustment facilities and an arrangement to permit a certain amount of lost motion. These facilities enable the box to be set to detect a switch opening of 5/32 in. and yet permit a compression of the lost motion of more than 1/8 in. This arrangement gives practical working tolerance.

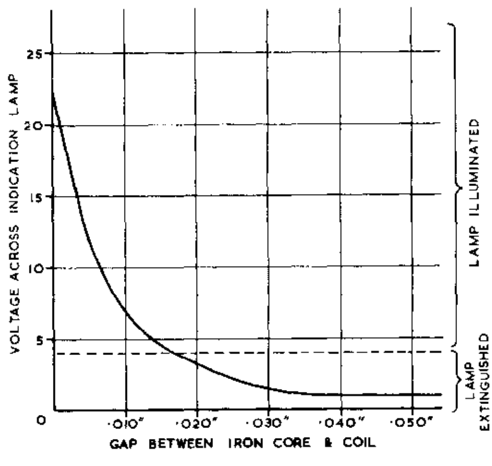

Fig. 24. Relationship between Detector Gap and Lamp Voltage.

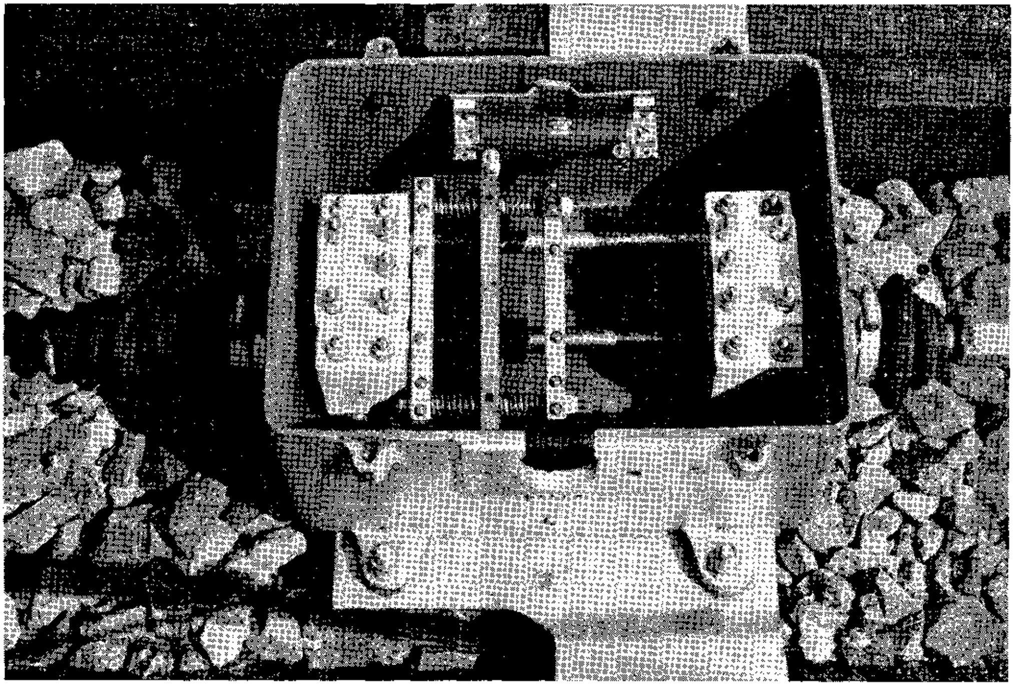

Fig. 25. Contact-less Point Detector Box.

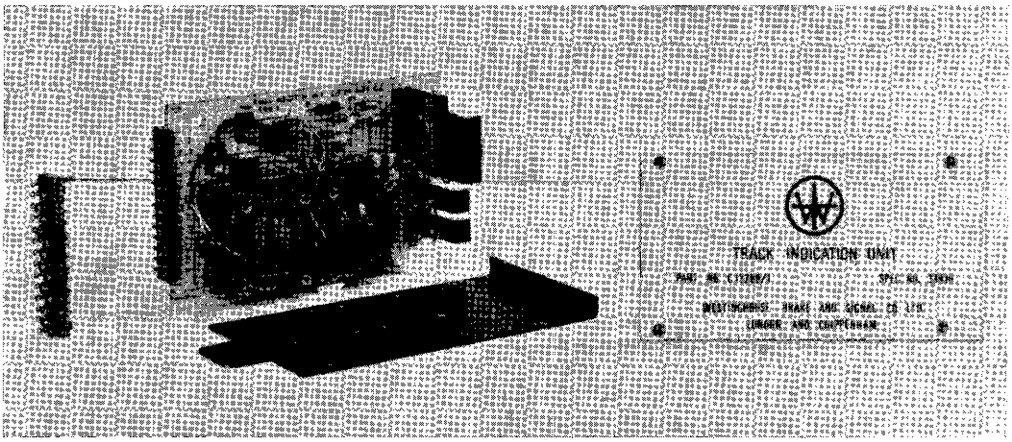

Fig. 26. Printed Circuit Card Northumberland Park.

These electronic circuits do not meet the stringent requirements of "fail safe" signalling, and indeed the wiring and spacing of terminals is certainly to a lower standard than that employed for safety signalling circuits on London Transport; but nevertheless, using A.C. instead of the more conventional D.C. for the interlocking circuits means that the transistors employed are being continually switched from the on to off state for a signal to be passed on. This ensures that a faulty short circuit or open circuit transistor will not remain undetected until revealed by a wrong side failure. Fig. 25 shows a photograph of the detector box installed on a set of points at Northumberland Park Depot and fig. 26 shows a photograph of the printed circuit cards.

Train movements in this depot, which are all non-passenger, are of course all controlled to a maximum speed of 10 m.p.h. This system described will provide the necessary flexibility with control from the central point for the marshalling of trains, for the transfer of train from one road to another, into and out of the Chief Mechanical Engineer's depot, and for the day-to-day requirements of passing trains through the washing machines.

11. ACKNOWLEDGEMENTS

I would like to thank Mr. R. Dell, Chief Signal Engineer of London Transport, for permission to write this paper and also acknowledge the assistance I have received from my colleagues in their criticism and help in producing the diagrams. I am extremely grateful to them for their valuable assistance.

DISCUSSION

Mr. H. Duckitt said it was a pleasure to open the discussion on the paper that had been so ably presented that evening by Mr. Smith. A paper on the basic signalling principles of the Victoria Line was timely and carried forward the story of London Transport's Automatic Train project from where the paper read two years ago by Mr. Kent and himself left off. The Hainault-Woodford automatic train installation had already been a Mecca for visitors from all corners of the world, and he was sure that the Victoria Line would in due course, become a show-piece which would raise the prestige of British signal engineers in the eyes of those abroad who were contemplating the use of some degree of automation in their metropolitan transport systems.

He would like to suggest that it would be appropriate for the Institution to have a further paper presented when eventually the Victoria Line was operative. He thought that such a paper should deal in general terms with all those automatic features which were to be used and which were the responsibility of the Chief Signal Engineer. The paper would, therefore, deal with automatic railway operation as a whole and not necessarily confine itself solely to automatic train operation. He expected that the Papers Committee already had something of the sort in mind.

He had a few comments and some questions for Mr. Smith. First: he noted that on page 79 a stopping accuracy of plus-or-minus 5 ft. was quoted for a station stop. That was better than had been claimed before. Was that higher accuracy due to the slightly greater number of command spots which were to be used on the Victoria Line in the speed range from 25 down to 8 m.p.h., or was there some other reason?

Secondly: it was mentioned several times, on pages 78 and 79, that a train speed in excess of 22 m.p.h., with the train receiving 180 or 270 code, would cause an emergency brake application. Would Mr. Smith clarify the position, please? His understanding was that 22 m.p.h. was the controlled running speed on 270 code for example, and that the emergency tripping speed was a little higher at 25 m.p.h. Was that still so for the Victoria Line?

Thirdly: if one was dealing with an installation on the Victoria Line then, since that was a completely new line, the track circuits could be laid out in the first instance to obtain the best possible headway, using the coded track circuits and the transmission of safety code information to the train. Was he right in thinking that if one was converting an existing line from manual to automatic train operation that the installation would in fact be in two stages? For example, in the first stage the coded track circuits would be provided but would remain, section-wise, as for manually operated trains. Then new automatic trains would be brought into service gradually, and when all the trains had been brought into service on automatic working then, after that, the track circuits could be re-sited to give the optimum headway for the automatic trains. What arose, of course, out of his question was whether the conversion of an existing line was a feasible and economic proposition.

Fourthly: the paper dealt with the special track circuits in the Northumberland Park Depot and also with the coded track circuits used for the main running line. On the Hainault-Woodford section there was a checking of the safety code equipment before the train left the depot. Was there to be any checking of the safety code equipment on a train prior to its departure from the depot to Seven Sisters, or were there any special arrangements for doing checks as the train proceeded, presumably manually driven, as it left the depot area?

His last point was to have been a question, but perhaps he might merely make a comment regarding slide No. 20. He might add that in other quarters there had been some suggestion that, perhaps, specially selected micro-switches could be used for point detection in lieu of conventional fixed and moving contacts. Would the author like to state his preference for future point detectors; that is, should they proceed from conventional contact arrangements to micro-switches, or would he prefer to go for the contactless detector which was shown in the slide?

Mr. V. H. Smith, thanking Mr. Duckitt for his comments and answering the questions, said he would take the stopping accuracy which was mentioned first. On the Hainault line the limits were set at plus or minus 7 ft. 6 in. and he hoped they were going to do better on the Victoria Line and get 5 ft. Whether this was achieved because of the additional spots, time would tell. They would have to wait and see. They would certainly like to get 5 ft.

The 22 m.p.h. was certainly a controlled speed, and in fact tripping took place at 25 m.p.h. The difference, really was a tolerance which allowed for slight errors. He thought he had stayed consistent in the paper, and talked of the train at 22 m.p.h. and overlap at 25 m.p.h., so the 3 m.p.h. was the tolerance.

Installation of automatic trains on existing lines: he could only agree that it was a big problem. He was sure that when they decided to do that they would, in the way Mr. Duckitt had described, use the existing track circuits and convert to coded track circuits, put automatic trains on, and then adjust the track circuits. That sounded one way of doing it. He was not in the position to say more than that at the moment. It was not a thing to which they had given a lot of study.

Checking of the safety code on the train: they would do a similar thing at Northumberland Park to what was done today at Hainault. They had code facilities to check the train in the depot. The Chief Mechanical Engineer could ascertain that his equipment was all right before he let it go. Once it left the depot, that was to say from the reception road, down the tunnel onwards, it was an automatic train.

Safety circuits for point detection: the thought of putting micro-switches on to points he found to be horrible. He would not go so far tonight as to say that he was prepared to put the contactless detector on as a safety installation, but he was prepared to give a good deal of consideration to it. They had only had the box a month or so. They had not really run trains over it, and did not really know, but he thought it was attractive and was a thing that would come.

Mr. H. W. Hadaway said he would like first to comment on a point Mr. Duckitt had already mentioned. That concerned the Northumberland Park Depot circuits, and he would like to press Mr. Smith a little harder on the question of type of circuit and suitability, in his opinion, of application for full safety use. In the way in which he had explained the circuits, the circuit form as such tended to meet the requirements of fail-safe. Mr. Hadaway thought he would say, with good reason, that one would want to try out those circuits in places such as depots, so as to get experience from all points of view. That would include the experience not only of wrong-side failures but also of right-side failures. So it was a complete experience that would be gained. But if Mr. Smith would look at the question assuming that the trial had given satisfactory operation, there still remained to answer, was he satisfied as to the principles being applied? If the principles that he had demonstrated that night were satisfactory, were they in the form that he would be prepared to put in full safety signalling—if not, why not? And if he was not entirely satisfied, what proposals would he make for modifications so as to be able to regard them as fully fail-safe?

His second point: Mr. Smith had mentioned the question of the programme machine operation and had spoken of the way in which the programme machine looked after the service operation up to a certain extent of deviation from normal train service operation. He would like to hear his views as to the possibility of going a step further, maybe not at present on the Victoria Line but looking further ahead. To what extent could he prophecy as to how far the programme machine would be able to take over, not at the present limited form of service disorder, and at which point the regulator took charge, but for the machine to provide control for all variations of timetable, and how would he foresee this being brought about?

Regarding the moving block he had heard Mr. Dell say, from that platform, that it was one of the things that he had heard of for many, many years, but it had never been made clear to him how it was made effective. Publications in the technical press referred to the moving block concept, and articles on the proposals for the San Francisco tube had quoted the moving block as an absolute essential for that system. He would like to hear, during the present discussion, other people's views on " moving block ". Whilst it was a useful thought that the moving block allowed trains, during movement from one station to another, to close up gradually, nose to tail, so that eventually there was achieved a solid line of trains, he had never yet been able to resolve the problem of arrival at the next station when the train at the head of the queue stopped and of course all the others behind stopped too. So long as trains stopped at stations, and that was the only time there was a headway problem, he could not see how a moving block was ever going to be capable of application.

Mr. Smith had made mention of the fact that solid state circuits were used on the train safety equipment. There again, it was a question of the fail-safe aspect. What principle was involved in the circuits used there, to enable the full requirements of " fail-safe " to be met?

Following a point that Mr. Smith made, when the requirements of safety resulted in the train being emergency-braked, and the final step in the chain for the brakes to be applied by air pressure, he would like to ask was this really fail-safe? As he saw it, developments of future systems for automatic operation would cause the boundaries between departments and sections to become blurred, and eventually to disappear. The safety of the system must be regarded as the complete system, and not just that part which now applied, say, to the Chief Signal Engineer, or the Chief Mechanical Engineer.

Mr. Smith had said that the red aspect was switched out and the banner then came alight. They had, he knew many battles on this domestically, and he was still partly of the school of thought that it was best to keep the red light switched on; the qualifying banner then operated in a similar way to a disc signal with a colour light signal. So he would like Mr. Smith to justify why he thought it was a good thing to switch out the red light.

The detector box which they had seen that night had one design feature not so far mentioned. The series resistor which Mr. Duckitt mentioned performed a dual purpose. It had to be present, so that when the detector box was in mid-stroke, and therefore the impedance of the two windings was low, the resistance limited the current. It did, of course, consume power and give off heat, and from a design point of view would normally be considered undesirable. The resistance had been placed in the detector box for the heat to prevent freezing, and to save putting a lamp in the box, which would otherwise have had to be done.

Mr. Smith showed a view of the apparatus located in the tunnels, with a form of joined-unit equipment cases. Equipment would be pre-wired as much as possible, with the intention of limiting the time required for site occupation of the tunnels.

Mr. Duckitt made mention of the conversion to automatic operation of the existing lines; that, of course, was a very thorny problem. It was one of which the

London Transport Board was very conscious, and a policy would need to be evolved so that future works would anticipate the conversion to automatic operation. That was a subject in itself, and one which they could not possibly cover that night. He believed that it would be possible to put in the coded track circuit system " first-go " to meet the final requirements of the automatic trains, with only minor additions and alterations which would be in " plate-rack " form for the change to automatic train operation.

Finally there was the question of the 5 ft. accuracy of the station stop. Improvement was obtained by a series of tests that were made where the braking spots below 22 m.p.h. speed were rearranged at less than 5 m.p.h. intervals, which had been the original layout arrangement. A braking spot was used at the lowest limit of 7.5 m.p.h. It was the correction of the train speed in the lower values which allowed the greater accuracy of 5 ft. instead of 7.6 ft. to be obtained.

Mr. V. H. Smith in reply said that Mr. Hadaway had started with a suggestion that the non-safety circuits used at Northumberland Park depot, be used for safety work. He was not quite sure if he was referring only to the point detection circuit or to all of them. Taking the point detection circuit first: He had a strong feeling that with the circuit as they had it now, and replacing the indication lamps by two relays, a normal relay and a reverse relay, they had something like an ideal safety circuit. He thought it had the makings; he could not see any snag at that moment. One had obviously to take precaution in the cables so that there could not be cross-connections as one proceeded from the apparatus to the relay room, but having taken those fundamental safeguards he thought it had the makings of a safety circuit. But again, with somewhat natural caution, he wanted to know a little more before he could fully recommend it.

The other side of the control circuit: the track circuit and track locking; could they use this for safety work? There were certain safety features built into them inasmuch that the signals passed from one card to another or into the card and out of the card, were a.c. By using that mode one did cause transistors to be continually switched from the " on " to the " off " state, and the short circuit or the open circuit did not allow false signals to go forward. To that aim they were fail-safe but—and this was rather a big but—the standard of the wiring was not what they had come to regard as safety wiring. The cards on the rack demonstrated were the actual ones; they were placed at that distance apart; the connections were very close by safety standards, so that consideration had to be given to false connections between terminals and what effect that might have. Even in the standard of wire that they had used the amount of insulation was less than they used for safety work, and he thought there was a possibility that they might have to review the way the cards were put together, the way the connections were made and such features. Perhaps if they developed them in that way there was a potential, but again one had to look into this very closely for the use for safety work.

Programme machines: the use of those under conditions of service disorganisation was possible; limited facilities were built into the programme machines, so that if the service departed from programme the programme machine could deal with the alterations. For instance, with a converging junction, if the train was late on one arm and the next train arrived from the other arm the machine could cope with it and take the train out of order, and warn the regulator what it had done. It had been built to cope with limited things of that nature without intervention by the supervisor. It was quite feasible to build in to the system means for dealing with even more elaborate arrangements. For instance one could think in terms of a complete break down at a particular place, so that the trains could not be moved, and it was necessary to reverse services on either side of the disruption. It would be quite feasible to have a spare roll that could be pushed into the machine to deal with all trains which had to reverse. It would be possible to provide another machine and allow the regulator to switch that in so that he could say " I have emergency type A, and I want emergency type A working ". It would be something pre-planned, which would be better than the present method. This could be envisaged in the not-too-distant future.

Solid state equipment on the train: Mr. Smith confessed he was not very knowledgable on that; in the main they were magnetic amplifiers.

Switching out the red light, or leaving it on: he hardly knew which way to go on that. He agreed one could leave the red light on and have the banner on top of it; there was some merit in that. Likewise the arrangement which they had chosen, to switch out the red light and leave the banner on its own, also had possible advantages. He did not think it mattered very much; in fact he believed at one time they were proposing not to have a banner, but to let the automatic train go past the red light, until purists persuaded Mr. Dell he could not do that. If they had the banner he was not sure it mattered whether one left the red light on or not.

Heat in the box: Mr. Smith thanked Mr. Hadaway for drawing attention to that; it was a good idea to have that resistance there.

Apparatus in the tunnel: the illustration in the paper was an artist's impression; the box did not exist yet, so he could not get a photograph. He did the next best thing. It probably would not be quite as drawn, but it would give some idea of what they had in mind; a pre-wired location case or series of cases, with a signal at the end, which could just be put up. In fact he thought the artist had not put enough cables in; there was just a main feed in and out, but he hoped it served its purpose.

Mr. E. A. Rogers said he also would like to congratulate Mr. Smith on a very comprehensive paper which formed another stage in the saga of the Victoria Line. He agreed with Mr. Duckitt that it must be brought to a Grand Finale coincident with the opening of the line to public service.

His questions mainly related to the coding of the track circuits. Mr. Smith had not given them a lot of detail on the form in which the coding was generated or distributed. Could he say whether the codes were generated independently at each location, or were they carried on continuous frequency bus lines running throughout with distribution points from which the code was injected into the tracks along the system? If he remembered rightly the Japanese, when they used their multi-frequency system for cab signalling, had concentrated all their equipment in locations placed a very long way apart, and that enabled them to use a very small number of code generators, because they were common use to a large number of track sections. He asked to what extent London Transport used a common system, and to what extent they were individual.

Could Mr. Smith also say what steps were taken in the code generation to check that the code being generated was the right one, and what happened if it were not; what extent of drift was permitted before it was regarded as being unacceptable? Again, on a similar basis, should any one code be regarded as having failed, did that particular track section then receive no code at all, or could steps be taken to feed that particular section automatically with the next most restrictive code, and so avoid the train getting a complete stop indication?

To come now to the point on which Mr. Hadaway had invited comment from the floor; that was " moving block ". They found that a lot of new-comers into the signalling field kept telling them the moving block was the answer to all line capacity problems of the future. This, he thought was right if the trains just kept running round in a circle and never deviated from the one line. As soon as one came to a station or deviation, or as their friends called it, a " bifurcation " one had obviously to keep any one train back braking distance from the points forming that bifurcation, so as to make quite sure the points had operated correctly before the train proceeded. So the concept of moving block, he thought, fell down straight away for that reason. He had not yet seen any real justification for the cost involved in providing it. It was not any use packing up the straight automatic line between stations if the trains all piled up at the nearest junction.

Finally, in a slightly lighter vein, he would like to congratulate Mr. Smith on a detector box, where the lineman could tell whether its circuit was made up without even opening the lid!

Mr. V. H. Smith replying said he would take the last point first. He was not sure that he should have the credit for the detector box; it should go to the designers. They built in the feature that enabled one to tell if it was made up without opening the lid.

Code generators; code bus bars: perhaps tonight they had put too much emphasis on the signal location. They hoped those were going to be rare things in the tunnel, to some extent. On the Victoria Line each station would have two apparatus rooms, one at each end of the platforms. Inside the relay room would be bus bars which would be fed from code generators; and the hope was that they would provide sufficient for all the track circuits they needed in that area. Owing to the fact that there was a limitation on how far one could go in distance, in cabling and so forth, that feature, and the distance between certain stations, would make it necessary to put something in the tunnel; in which case they would have their own code generators in the tunnel.

Regarding the code generators and the correctness of the code, they did not make any check whilst *in situ* but the code generators were similar to those on the Hainault line, where they made no check. The 120, the 180 and 270 were all pendulum driven, and the pendulum was chosen because of the reliability. The only way the rate at which the pendulum swings could be changed was for the weight to fall off. If they had lost the weight they did not get any signal anyway so they knew all about it.

The 420 code generator was an electronic one, and if that went off-time it could go slower, in which case it would give a more restrictive signal, which did not matter. If it went faster that was not very serious until it reached the point of failure. Then they knew all about it.

Referring to the question of code generator failure, the bus bar would then be dead, and one would not be able to get that particular code on any track circuit. No provision was made to switch to another code. He thought that would not be very practical, and in any case not very wise, because if one did things of that nature and got trains in by some trick of that kind, one ended up by having failed equipment which no-one knew about. He thought it was better to have a complete failure, and to know all about it and go and put it right, rather than equipment which was not performing as one thought it was, and getting by with some trick which involved slow running which nobody reported.

Mr. A. A. Cardini said he had one or two questions. The first one was on Fig. 3, the braking curve. It was on the typical train approach curve where he noticed that just after passing the 4 kc command spot there began a deceleration. The approach speed there was of the order of 35 m.p.h., certainly under 40 m.p.h., and he was a little mystified as to what caused deceleration to start. Either he had missed something or else it was just the figure which was a little loosely drawn. In section 3 on the same page Mr. Smith began to talk about the maximum speed which a train achieved, and went on to speak of maximum permissible speed. He was again puzzled as to what that maximum approach speed could be. How was exceeding it prevented? In connection with this, in Fig. 4, was it not a pure coincidence that the maximum approach speed overlap of 30 m.p.h. should continue with the 22 m.p.h. speed point on the braking curve? That led him on to ask what was the criterion which had led to the selection of that speed of 22-25 m.p.h.? He had a feeling it was somehow related to the maximum likely approach speed to be encountered in the particular circumstances applicable to the Victoria Line. If the maximum approach speed—again referring to Fig. 4—rose considerably, then it seemed that the 20 kc spot would move further away from the signal position, so that braking would commence much earlier, and the train would have reached 22 m.p.h. long before it had reached the beginning of the overlap distance. Here again he was not quite clear, but it seemed to him that there was no relationship between the maximum speed and the selected controlled speed, and there would thus be, possibly, a loss of headway through excessively prolonged and unnecessary running at 22 m.p.h. Was it in fact the case that the 22 m.p.h. had been arrived at from a consideration of obtaining an 82 sec. headway through the stations, under either manual driving or under controlled approach working?

Another point was that Mr. Smith said that the lineside signalling was being kept to a minimum, and in fact signals were only being provided at the stations. But there were connections—although only a very few—along the line, and he was wondering what provision was made there to protect the approaches. He was thinking of a train approaching under manual control at 10 m.p.h.; how was a converging movement safeguarded?

Mr. V. H. Smith replying said that on the train there were three rates of braking—a minimum and a maximum; and the effect of the command spots on the train was to cause one of these three braking conditions, if appropriate. "In the particular example taken of 4 kc, a typical train approach curve passes through the lower portion which is marked for giving a minimum brake application. The 4 kc command spot is the 40 m.p.h. point, and the train proceeding at 35 m.p.h., and in anticipation it would get a minimum brake application. Referring to the diagram it will be seen that at the following point on the 3.5 the curve is drawn just within the minimum area. The next one is in the normal, and one can imagine it just caught the minimum on the 3.5, overshot the 2.5 and got into the maximum. It is hard to tell on the curve. Prior to the 4.5 kc it will be seen that the line passes beneath all three conditions and no brake application occurred."

The term " maximum speed " was the actual maximum speed, not the permissible but the possible. That was given by the Chief Mechanical Engineer who stated " This is the maximum speed my train can do on this section ". On Fig. 4 the 30 m.p.h. overlap coinciding with the 22 m.p.h. point on the braking curve was coincidental. Mr. Cardani's comments were quite correct. If one catered for a much higher speed overlap then it was found that the service braking curve had stopped much too soon, and the train stopped too far away from the signals. With higher speeds one would have to resort to tricks to slow the train to 22 m.p.h. and then let it run towards the signals. He had skated over that point, and drawn the curve for 30 m.p.h., which he hoped illustrated the point without giving too much complication. He agreed that it gave complications at a greater speed, although of course, at the greater speed the advantages were greater, because the train can be moved in closer.

The choice of 22 m.p.h. stemmed from a long way back in their history, when they decided that the best headway could be achieved by trains doing 25 m.p.h. through stations. Having derived that they stuck to the 22 m.p.h. for that purpose. It was also the restrictive speed they had for the train, and which they used for other purposes, such as speed restrictions for junctions and so forth. So it was quite a convenient speed for safety without the complications of having 15, 20, 25, 30 and so on. So really they would be faced with two conditions, either running at 22 m.p.h. or full speed, whatever that happened to be.

Regarding Mr. Cardani's last point there would be signals at junctions, and in the same way as he had shown a home signal approaching in the station, so there would be a home signal approaching a junction. In fact that very figure, Fig. 4, did show a signal at a train junction, and it would be positioned at 25 m.p.h. overlap from the fouling point.

Mr. B. Reynolds raised the question of the effect of weather on the Northumberland Park track circuits. That was prompted because he noticed on the diagram of Northumberland Park that quite a number of the track circuits had many limbs to them, and that kind of track circuit was rather more prone, perhaps, to suffer from the effects of weather. Looking at Mr. Smith's diagram 20 it seemed that the voltage on the rails would be of the order of about 4 to 6 volts from his 12 volt feed through the resistor, and then that was required to be stepped up to some 30 volts for operation of the track circuit interlocking cards. If the ballast got wet the voltage on the rails was reduced, and because of the step-up factor of about 5 to 1 the 30 volts was going to be even more seriously reduced. He would like to ask Mr. Smith if he did expect trouble from wet weather due to that effect.

Then he asked if the opportunity had been taken to cable the non-safety circuits in the Northumberland Park area in multi-core cables instead of the more conventional two-core and single-core cables.

Next Mr. Reynolds raised a point on the contactless detector box. It seemed to him that since such a very small gap between the armature and the transformer cores was necessary to achieve lighting of the points indication lamp (see Figure 24) and presuming residual pins were already fitted to the armatures (giving a gap to start with), that a small piece of dust or scale intruding between the armatures and the pole pieces could very well fail detection. Was not Mr. Smith afraid that in the environment in which these boxes worked such a thing could happen?

Lastly, on the general layout of the Victoria Line, he asked if the opportunity had been taken during the planning of the line, to build the stations on a hill so that advantage could be taken of the rising gradient for more effective braking, and of the downgoing gradient at the start-off for quicker acceleration?

Mr. V. H. Smith replied that the specification for the track circuits at Northumberland Park required them to work with a 5 ohm ballast resistance, and under those conditions to shunt with a 1-ohm shunt. Perhaps Mr. Newby would advise him. He believed that model had a 5-ohm ballast resistance in, and that the push buttons were 1-ohm shunt. He thought that would give them good track circuits. Experience had shown that if one could work track circuits with 5-ohm ballast, and get a 1-ohm shunt all would be well. The proof of the pudding obviously was when they got them working. They had certainly thought about it, and resistances were hung on the back of that model to produce that very thing.

The cables for Northumberland Park were multi-pair cables, in fact, telephone cables, running from the relay room out to the apparatus—20 band conductor multi-pair telephone cables with P.V.C. insulation.

With regard to the detector box, there are no residual ins. The transformer is a.c. so he did not think there was any fear of it sticking, or anything like that. He agreed that a slight movement away from the coils made it fail, but he emphasised the compression that took place, in as much that the detector rod moved the core against the coil, and then continued to travel for about $\frac{1}{8}$ in. compressing on the springs. When the switch moved away, nothing happened at the detector core until the switch was opened about $\frac{1}{8}$ in. By that means one had a much more practical arrangement. The box was connected direct to the switch, and the movement in the box, with the exception of that lost motion, represented the switch movement. It was just a straightforward operation.

In answer to the last question the Victoria Line did not have any up and down gradients as described by Mr. Reynolds. It was really the province of the Civil Engineer and he could say whether any consideration had been given to it.

Mr. M. E. Leach said that at the bottom of the text, on page 78 there was reference to a 15 kc command spot which initiated coasting of the train. An activated command spot of that type caused the driving motors to be cut out and the train was allowed to coast. Presumably the location of those command spots was based on achieving optimum performance of the train from a driving point of view. Perhaps Mr. Smith would tell them a little more about this. What was not clear to Mr. Leach was, having given the 15 kc command spot to cut out the driving motors, how did one re-energise the circuit to get the train to continue motoring if that became necessary?

It had also occurred to him that there was a refinement which could be added to this part of the control arrangements. If the trains were allowed to coast in order to achieve optimum performance from the traction current point of view, then, if the service was perhaps slightly behind schedule, the command spots could be disconnected by the traffic regulator, so that the traction current could be kept on the motors longer and the service speeded up just that small bit.

Perhaps Mr. Smith could comment on this possibility.

Mr. V. H. Smith replied that the 15 kc coasting spots would be positioned where the motors could be cut off and the train allowed to coast to the next station. They had to be positioned in such a way that one would not be required to re-motor, short of having to stop at signals and start off again.

The point mentioned about cutting them out if the service was late, was interesting and they thought that in all probability they would have some remote control of the coasting spots possibly on a north-bound and southbound direction—one circuit for north and one for south. So if they were for example late running north the coasting spots could be cut and time gained in that way. The real object of coasting was, of course, for economy in power.

Mr. Hurman asked if the new track circuits with the electronic features could be used on tracks carrying return traction current. Also, were the points going to have a bolt on them for facing movements, or was that just left out because it was a running movement on a siding, for carriage storage facilities?

Mr. V. H. Smith replied that with these track circuits the running rails would not be carrying traction current. The system on London Transport was a 4-rail one, where they had 2 conductor rails, one positive, one negative, and the running rails left free for use with the signalling circuits. He would not like to use their track circuits where the running rails were used for traction current. He thought that would be fatal. There were no locks on the points. One had to remember that a depot of that nature hitherto had been worked by a man on the ground working long levers at the points and just setting the points and working the trains about. What they had done was to take that man away, and sit him up in a control room and given him facilities to work the points remotely. In doing so, of course, they had reduced the number of men required. They had given him a long arm, so that he could sit in comfort up in his glass box and watch everything that went on, and work from there.

The President, Mr. R. Dell in concluding the discussion said that they were indebted to Mr. Smith for his paper, for the way in which he had summarised a long paper, and interposed some interesting slides.

They thanked him also for the way in which he had answered the questions,—or nearly all the questions. There was one to which he said he had not an answer.

He was sure they would wish to extend a very hearty vote of thanks to Mr. Smith for his paper, and for the work he had done in presenting it that evening.

Provincial Meeting of the Institution of Railway Signal Engineers

held at

The College of Technology, Sackville Street
MANCHESTER

on December 7th, 1966

The President (Mr. R. DELL) in the chair.

At this meeting Mr. V. H. Smith read his paper entitled " Victoria Line Signalling Principles."

DISCUSSION

Mr. E. G. Brentnall opening the discussion said that the paper showed that a very interesting system of signalling was to be applied on the Victoria Line. The automatic system was very simple indeed, but he was sure it would give all the necessary controls and facilities for the very onerous traffic conditions of London Transport.

It should be noted that the track circuit overlap principle of London Transport was very different from that of the B.R.B. Main Line, as full emergency braking distance was allowed. The main line overlap distance was 300 yards for 3-aspect signalling and 200 yards for 4-aspect signalling, and existed in general only to give protection if a train should slide past a signal. If all trains could be fitted with power brakes, he considered that the main line overlap length could be reduced still further.

He was most interested in the remarks in the paper regarding moving overlap controls, which resulted in a train being permitted to approach closer to the train ahead. For a moving overlap installation it was necessary that continuous controls be transmitted from the track to the locomotive.

He would like to draw attention to the fact that experiments were being carried out with automatic controls for main line railways throughout Europe. There was an organisation for research (O.R.E.) which was connected with the International Union of Railways, and that organisation was considering the problem of automatic working with a view to arriving, if possible, at a standard arrangement. Various experiments had been arranged and British Railways were considering an arrangement where a conductor was laid along the four foot in a " V " shaped configuration, the length of the various " V " configurations varying in accordance with the maximum allowable speed at any point, which was arrived at from gradient, curvature, and so on.

He found the future electronic circuits of great interest. They were most ingenious and he was sure their use would be extended. Electronic circuits had been used on the London Midland Region in connection with remote controls to satellite interlockings in colour light signalling installations for both the Time Division Multiplex and Frequency Division Multiplex methods. So far the electronic systems had not been used for safety circuits, but a Frequency Division Multiplex type of remote control was proposed in schemes now being installed for safety circuits.

He felt that it was only an interim development, and that there would be very great developments in the near future with solid state circuitry in the signalling profession.

Mr. Whitehouse said that the fact of a Train Describer setting routes must obviously lead to routes being set on the immediate clearance or occupation of a track circuit. There was, therefore, the safety aspect and when it was permissible for a route to operate and if time was available for the route setting to be completed. How was that achieved, as it appeared to need quicker operation than relay timings would allow ?

The point operating apparatus seemed interesting and simple, but it was surprising to find it was all mounted in the 4-foot. What arrangements were made for maintenance and fault detecting? The 5/32" detection tolerance was greater than the British Railways standard. Was that detector purely for indication purposes and did they have a separate facing point detector for passenger movements ?

The training of maintenance staff: what proposals had they formulated for ensuring that maintenance staff were fully acquainted with the system when it came into use, to give speedy attention to faults and keeping traffic moving ?

There was difficulty in getting about the Manchester area due to road traffic conditions. Was it proposed to have maintenance staff strategically placed around the installations, and had account been taken of time factors for clearing faults ?

Mr. V. H. Smith said that in referring to train describer route setting a wrong impression had been given. The train describer did not set routes, the programme machine did that, but before doing it the programme machine confirmed with the train describer that the two were in agreement. That was no more than a signalman did ; in other words the signalman would look at his timetable to see whether a train had to go to A or B, and he then confirmed with the train describer. A programme machine did just that ; it looked at the timetable—holes punched into it—but before actually clearing it confirmed with the train describer. A warning was sounded to the supervisor if there was a disagreement, so that he knew all about it. If the programme machine was correct he pressed a button, and if the train describer was right he did nothing, and after a delay of one minute then the train describer was assumed to be right.

The time factor did not matter and many of these installations to-day were running on relays.

The installation of the point equipment in the four-foot was standard practice on London Transport. In tube tunnels there was virtually no alternative to the installation of the equipment within the four-foot, as the clearance on either side of the line was so limited as to exclude the installation of equipment outside the gauge lines. Experience on London Transport had shown that normally equipment in the four-foot did not present any problem.

The detection was set so that with the switch open 5/32" the indication would fail. The particular points that were demonstrated were for depot use and there were no facing pointlocks on these points. In order to train staff there was a Signal School, and the particular equipment which had been demonstrated would be placed in the school and the apparatus used for instructing staff. Likewise before the equipment was actually brought into service staff would have an opportunity of examining it on site.

London Transport had technicians stationed about London in various places. In the event of a signal failure one or more of these technicians were directed to the failure. If rail service was not operating then the technician would use a taxi. Experience had shown that to be the only practicable means of transport. Experiments had been tried providing the technician with road vehicles but the problem was where to park the vehicle in Central London.

Mr. Whitehouse asked where staff for maintenance purposes would be placed ?

Mr. V. H. Smith replied that the disposition of the technicians had not yet been finally decided for the Victoria Line. No technician on London Transport was allocated to a particular area or line, from failure point of view. In the event of a failure any technician was directed to attend the failure. For maintenance purposes a technician was responsible for a definite area.

Mr. Morris asked :
1. Are the facing points on the Victoria Line bolted or locked ?
2. The trains appear to me to be automatically driven—in future we might also dispense with the signals themselves.

Mr. V. H. Smith in reply said the facing points on the Victoria Line would be locked. Chairlock point layouts were used for that purpose, and he believed were exclusive in this country to London Transport. The feature of these points was that the locking device actually locked the switch to the stock rail and did not, as in the conventional facing pointlock, lock the switch to some point which is geographically related to the stock rail.

On the Victoria Line the intention was to provide only the minimum number of signals and if in the future the train operator was removed, as he might well be, then there would be no need to provide line side signals.

Mr. E. Wright said that he noticed that it was possible to pre-select the route signal. Was this not unsatisfactory due to passenger train movements ?

Mr. V. H. Smith replying said that pre-selection was used throughout the London Transport Area on passenger moves. It had to be with programme machines.

Mr. L. G. MacKean asked : " Am I right in saying that under normal conditions the train will run on green aspects and that the banner signals will be used only for closing up controls and at these times the red aspect will be suppressed ? "

Mr. V. H. Smith replied that trains would normally obey green aspects in signals, but during peak hours, with close running, closing up into platforms by means of banner signals would be provided. Where signals were provided for the protection of points or junctions there would be no banner, and one would expect a 25 m.p.h. overlap from the points to the aspect protecting them.

Mr. Foster said that looking at the diagrams in the paper he noticed that the clearing of the banner signal appeared to require one track circuit clear beyond the 25 m.p.h. overlap. In Fig. 11 it would be seen that the banner signal required track circuits 705d, 703a, 703b, and 703c. Was the intention to prove that the train in front was moving forward, and did that depend on the lines being signalled for a standard length of train ?

On the train it was interesting to see that relay circuitry was being replaced by solid state circuitry. Did that include the final safety circuitry associated with tripping the train in the absence of codes, or was mechanical tripping retained as a last resort ?

Mr. V. H. Smith replied that there was a standard length of train on the Victoria Line, but that was not relevant to the circuit arrangement. In Fig. 11 of the paper the banner signal relay was controlled by track circuits 705a, 703d and 703c, that was the control extended from the signal concerned up to the end of the next 25 m.p.h. overlap.

The safety box on the train was operated by solid state circuits. The trip had a normal energised valve such that when it was de-energised the brakes were automatically applied. That would occur under failure conditions, or in the absence of code received from the track. On the Victoria Line no mechanical tripping would be used.

Mr. Wright asked if some further safety feature was brought in for the next track to be occupied as well ?

Mr. V. H. Smith replied that the relays of a signal backlock, which was protecting facing points, required not only the appropriate track circuits clear but the operation of a de-energised rail circuit proving that the train had passed through the route. The de-energised rail circuit was installed at least a train's length from the points. All push-button installations on London Transport were provided with pre-selection facilities and were used by the signalman.

Mr. K. Morgan queried : " You do not cover for a train breaking down or a complete breakdown ? "

Mr. V. H. Smith said that in the event of a train breaking down in a tunnel it would be necessary for the following train to close up to the broken down train and propel it out of the tunnel. That was a rare operation, which had to be carried out under extreme caution and special rules had been devised for this purpose.

Mr. Blythe asked what sort of tolerances were allowable in the codes—plus or minus ?

Mr. V. H. Smith said that the code generators producing the codes at 120, 180 and 270 were operated by pendulums. That method of achieving the right rate was chosen because of the reliability of the pendulum. The only way in which the pendulum could alter was for it to be shortened, or for the weight to become detached. It could be accepted that the pendulum would not become shorter but it was possible for the weight to become detached. In this design the weight was a permanent magnet which passed coils and thereby when swinging generated a voltage in the coil. That voltage was used as a control for the code track circuit. This meant that the code generators were thus contactless. It also guarded against the possibility of the detached weight, because if the weight fell off then no voltage would be generated in the coils.

Mr. Blyth than asked what tolerances in actual setting on lower frequency codes were allowed ?

Mr. R. Dell replied that the tolerances of the setting of the frequency generators was that they were required to work in ambient temperatures from —5°C to +45°C and their accuracy throughout that range would be ±2%.

Mr. A. Clarke asked if there was any protection taken against the incorrect change of the pipes from the valves to the point cylinder ? Was there any difference in size of holes or anything of that nature ?

Mr. V. H. Smith replied that the model demonstrated, as they would have noticed had copper pipes for conveying the air to the point cylinder. In practice copper was not used and rubber pipes were laid on the surface of the ballast for this purpose. No difference was made between these pipes. They relied entirely on testing of the installation which was made after any alteration was carried out to ensure that the correct pipe had been connected to the correct size of cylinder.