Technical Meeting of the Institution

held at

The Institution of Electrical Engineers

Friday, December 7th, 1956

The President (Mr. J. C. KUBALE) in the chair

The minutes of the Technical Meeting held on November 19th, 1956, having been read and confirmed, the **President** welcomed Mr. D. Hagger and Mr. J. P. Raindle, who were present for the first time since election to membership. He then announced that following a proposal made at the technical meeting held on November 19th, 1956, that a committee should be appointed to study the subject of miniaturisation, the Council had that afternoon approved such a committee, which would commence its work very shortly.

The **President** then said he had great pleasure in calling upon Mr. O. S. Nock to read his paper on " Power Interlockings—Past History and Future Prospects."

Power Interlockings— Past History and Future Prospects

By O. S. NOCK (Member)

Diagrams—Inset Sheet No. 9

Introduction

In modern railway operating the demands of traffic upon interlockings tend to grow more and more exacting. The job of the signalman nowadays is not merely that of the old time " policeman "—that of regulating traffic along the line ; he requires to be something of a controller, and the tool nowadays available to his hand is not always adequate for the job. The link-up between the central Control and the men in individual signal boxes is at times rather nebulous, and to the onlooker it sometimes appears that to provide for the most efficient regulation of all the traffic on the line the functions of signalmen and Control need to be more closely combined. With the Modernisation Plan for British Railways getting under way, and with recent development in the interlocking machine itself, it is felt that an indication of what is technically possible would be of interest, in view of the operating difficulties which are so very

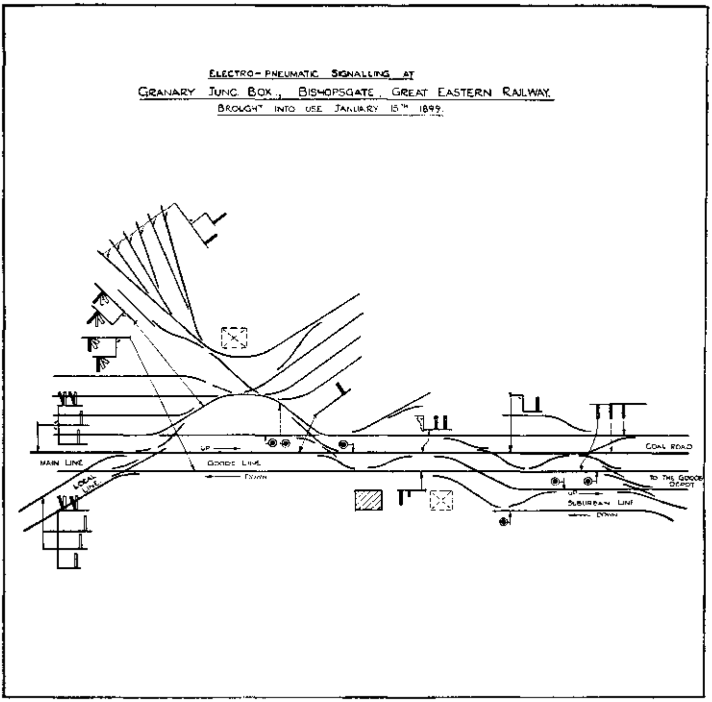

Fig. 1

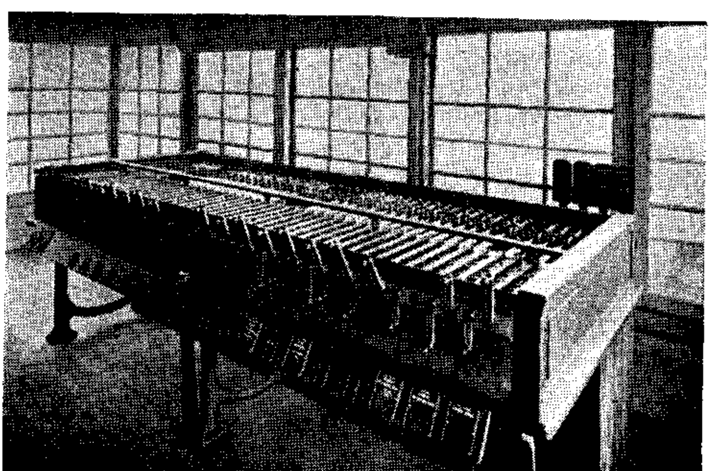

Fig. 2 Granary Junction—Great Eastern Railway

apparent in the handling of day-to-day traffic, and in view of the delays that are apt to arise due to signalmen having only a limited picture of the traffic situation as a whole. While it is true that in many instances the work of signal engineers has influenced the more recent trends in operating practice it is perhaps no more than natural that members of our profession feel sometimes that the operating requirements laid down do not always take full advantage of the technical advances made by signal engineers in recent years. In leading up to a sketch of prospects and possibilities for the future it is interesting, and indeed important to review the problem in historical perspective so far as the railways of this country are concerned, starting from the first uses of power in replacing manual work in the signal box.

First Uses of Power

By the " nineties " of last century some very large mechanical interlockings had been brought into service in this country. The interlocking was complicated, the signal boxes themselves were large, and many of the functions operated required considerable manual effort. Such working was taken as a matter of course, as was also the amount of walking up and down involved with a long interlocking frame ; taken no less for granted was the considerable amount of mechanical maintenance necessary for keeping rods, rollers, cranks, and so on, all in good order. In addition to carrying out their prime function—the safe regulation of traffic—signalmen had a considerable amount of physical work to do. The first steps towards the introduction of power lay in the direction of reducing that physical work. While the arts of block working, and " lock and block," were being developed to provide for safer working along the line, the first examples of the power actuation of signals and points were unconnected with the actual movement of the trains ; there was no track circuiting and no link-up with the block working.

The first power interlocking in this country was that at Granary Junction, Bishopsgate, Great Eastern Railway, put into service on January 15th, 1899. It is still at work today, and controls traffic passing from the main lines into the large Bishopsgate goods station. Originally 25 semaphore signals and ground discs, 43 points, and 1 facing point lock were operated from the power frame. Although this was not, even at that relatively

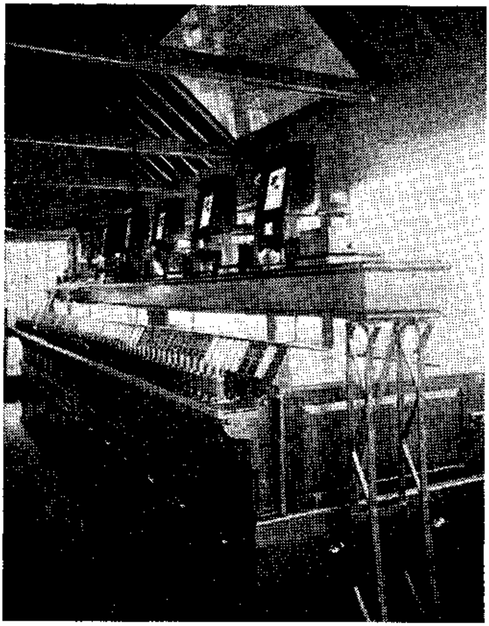

Fig. 3 Bolton—West Lancashire and Yorkshire Railway

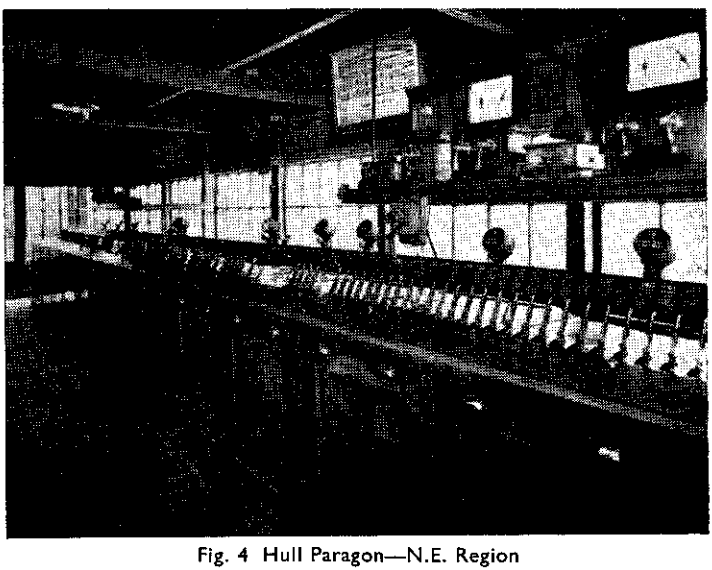

Fig. 4 Hull Paragon—N.E. Region

distant date, a large installation the layout extended over a considerable area, and if operated with manual frames would have needed two boxes. This installation created quite a stir at the time, though well-informed commentators were not slow in pointing out that Great Britain was already far behind America in her adoption of power signalling. At the time the Granary Junction box was opened there were no fewer than 49 installations on the same system—the Westinghouse electro-pneumatic—at work in the U.S.A., and in particular comparison was made with certain large English layouts, as follows :—

Station	Number of Trains per Day	Total Number of Levers in Frames
London Bridge (L.B. & S.C.R.) ...	665	378*
Liverpool Street (G.E.R.)	1070	424*
Boston (New Union)	775	127†

* = Mechanical   † = Electro-pneumatic

The installation at Granary Junction (see figs. 1 and 2) was a simple one to start upon, in that all points except one concerned freight movements only, and they were in consequence not fitted with facing point locks. In the light of recent operating experience with modern power interlockings it could perhaps be regarded as significant that the pioneer British installation concerned freight traffic, and freight traffic only. Again, the North Eastern Railway, which in pre-grouping days became one of the largest users of power signalling in Great Britain, made its first installations purely for freight working into and out of Tyne Dock. On the approach lines, in 1902 and subsequently, four boxes with electro-pneumatic frames were installed, including one with power operation of level crossing gates. The total number of levers in this group of installations was 168.

From these pioneer installations on the electro-pneumatic system there were developments on various divergent lines including :—

(*a*) All-electric systems
(*b*) A Low-pressure pneumatic system
(*c*) An Hydraulic system
(*d*) An electro-mechanical system

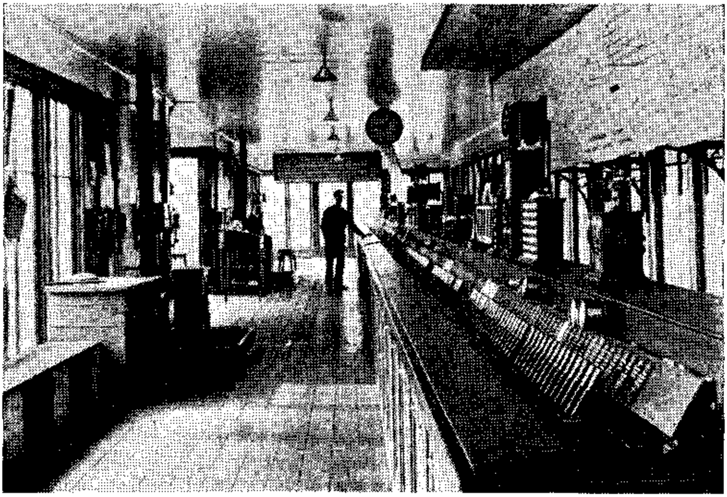

Fig. 5 Glasgow Central, Caledonian Railway

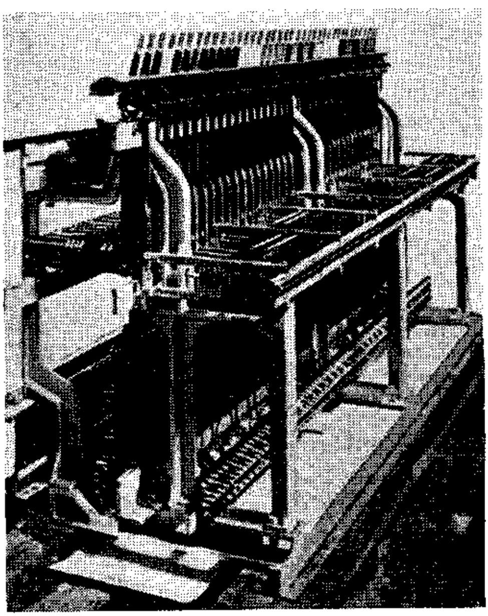

Fig. 6 Didcot Junction—Great Western Railway

Some typical installations are illustrated:—

Fig. 3 (*a*) Bolton, Lancashire and Yorkshire Railway.
Fig. 4 (*b*) Hull, Paragon, North Eastern Railway.
Fig. 5 (*c*) Glasgow Central, Caledonian Railway.
(The above three on the electro-pneumatic system).
Fig. 6 (*d*) Didcot, G.W.R. (All-electric).
Fig. 7 (*e*) Grateley, L. & S.W.R. (Low pressure pneumatic).
Fig. 8 (*f*) Salt River, South Africa (Hydraulic).
Fig. 9 (*g*) St. Enoch, G. & S.W.R. (Electro-mechanical).
Fig. 10 (*h*) Crewe, L. & N.W.R. (All-electric).

While the electro-pneumatic system developed on what might be termed orthodox lines, leading up to the very large frame installed at Glasgow Central Station, Caledonian Railway, in 1908, with 374 levers, the "Crewe" all-electric system and the Sykes electro-mechanical were the first, in their several ways, to group the levers so as to economise in cabin space. In the larger frames on the "Crewe" system, both on the London and North Western Railway itself, and at Severus Junction, York, the miniature levers were arranged in two tiers, while in the Sykes system miniature slides for signal operation were placed above the full-sized mechanical levers for the points. In none of these early installations, however, was there any track circuiting; the use of power for the operation of points and semaphore signals enabled the signal box layouts to be made more compact; in mechanical interlockings the minimum pitch of the levers is 4-in., whereas the electro-pneumatic system at first used $2\frac{3}{4}$-in. pitch, and in some types of power frame the pitch was still less. All this enabled the signalmen to handle the traffic more expeditiously, since the lever movements were no longer laborious and the locking frames themselves were very much smaller in extent. So far, too, the art of combination of levers was scarcely developed at all; the large installations at Newcastle, Hull, and Glasgow Central all had facing point lockbars operated by separate cylinders and separate levers in the frame, and while at Glasgow the number of semaphore arms was reduced by the installation of pneumatically operated route indicators, there was no reduction in the number of levers as each route had a separate lever in the locking frame. The days of electric selection were still some way ahead.

Fig. 7 Grateley—London & South Western Railway

Fig. 8 Salt River Junction—South African Railways

Some typical large interlocking frame arrangements may be quoted :—

Location	Railway	System	Signals	Points	Total No. of Levers
Bolton	L. & Y.R.	E.P.	123	43	83
Newcastle (No. 1)	N.E.R.	E.P.	236	119	283
Glasgow	Caledonian	E.P.	253	112	374
Clapham, East	L. & S.W.R.	L.P.	56	46	84
Crewe N. Jc. ...	L. & N.W.R.	A.E.	154	102	266
Victoria South ...	L.B. & S.C.R.	E.M.	225	140	269
Basingstoke ...	L. & S.W.R.	L.P.	37	40	68

E.P. = Electro-pneumatic
L.P. = Low pressure pneumatic
A.E. = All-electric " Crewe " system
E.M. = Sykes electro-mechanical

A limit was placed upon the size of interlockings by the need for the signalmen to see all trains, in the absence of track circuiting and anything in the way of an illuminated diagram. Indeed some authorities seriously questioned the wisdom of large, concentrations of control such as those exemplified by Newcastle No. 1 and Glasgow. The critics of early days were on firmer ground when they questioned whether as compared with mechanical working any reduction in the number of signalmen could actually be made. In the case of very busy layouts it was argued, with some cogency, that speed of operation was not the vital factor ; it was the actual number of lever movements to be made that governed the staffing problem. In the early power plants, in Great Britain at any rate, very little reduction in the number of lever movements was actually realised.

Even where the number of lever movements was reduced the procedure was at first received with some scepticism. Today it is amusing to read in an early treatise on signalling : " Of recent years a craze has arisen in France for itinerary levers, whereby the whole of a movement can be set by the operation of one lever. The idea seems at first to be delightful, but it is full of complications and a very costly fad, as in addition to points being worked when setting up any route—and some points may be concerned in several routes—they must of necessity be capable of being worked

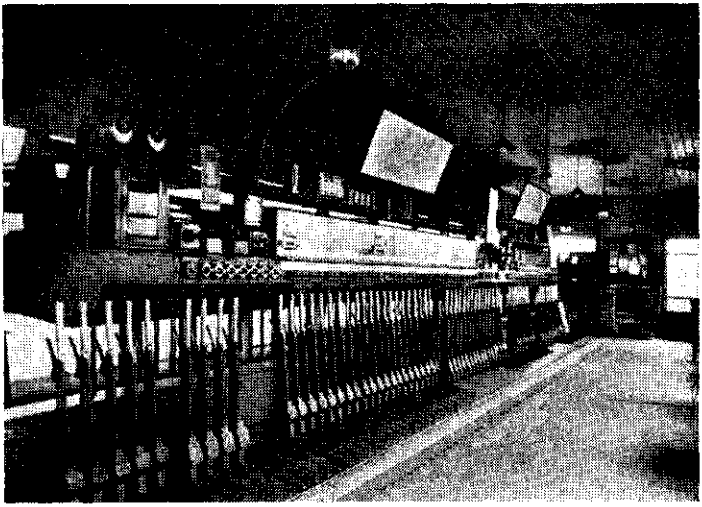

Fig. 9 St. Enoch, Glasgow—Glasgow & South Western Railway

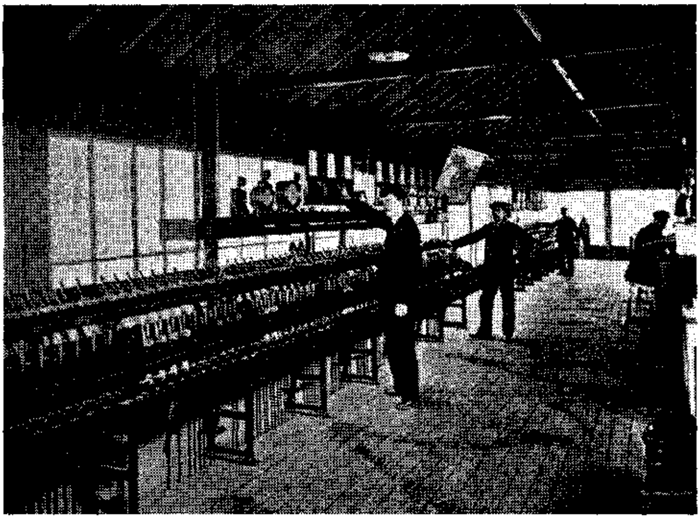

Fig. 10 Crewe—London & North Western Railway

independently. Further, a minor alteration in a scheme will probably upset the whole situation, necessitating the rearrangement of the point and signal connections and the remodelling of the locking frame."

While the spectre of complications arising from changes in signalling would evoke sympathy from many a modern signal engineer, with the large amount of drawing office and cabin work inevitably involved, the advantages of route working and relay interlocking have been so abundantly shown that complicated detail work in the event of alterations has come to be regarded as "just one of those things."

Development of Track Circuiting

In the first decade of the twentieth century a few isolated installations of track circuiting were made in various parts of the country ; but apart from the special conditions that gave rise to the use of continuous track circuiting on the London Underground Railways it was the accident at Hawes Junction, Midland Railway, in the early hours of Christmas Eve 1910, that gave a fillip to the widespread introduction of track circuiting as a means of detecting the presence of trains or vehicles in positions where they could not readily be seen by a signalman.

It will be recalled that on that occasion, during a spell of heavy traffic and much movement of light engines, the signalman concerned forgot that he had two engines coupled together and bound for Carlisle standing at his down advanced starting signal (see fig. 11). The enginemen themselves omitted to carry out Rule 55. When in due course the signalman was offered the down midnight sleeping car express from St. Pancras he accepted it at once and pulled off all the down line signals. The two standing locomotives moved away, and after a short distance were overtaken by the express, with disastrous results. Sir John Pringle conducted the Board of Trade enquiry, and in view of the signalman's forgetfulness, and the failure of the crews of the light engines to carry out Rule 55, he recommended that " special action appeared to be necessary to impress upon them the importance of obeying the Rule at other centres where detentions are of frequent occurrence and that to prevent any possible misunderstanding some further elaboration of the Rule was advisable."

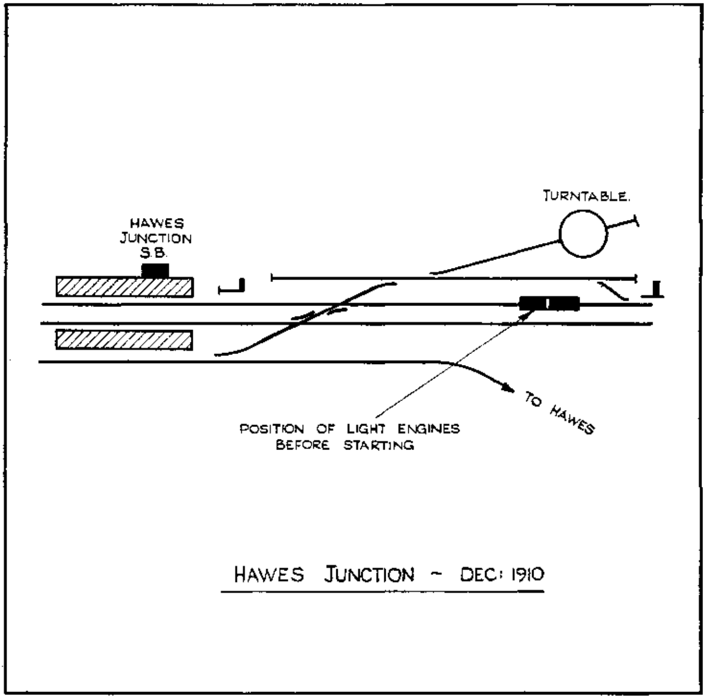

Fig. 11

When three years later the Midland Railway was unfortunate to sustain another serious accident on the same stretch of line, at Aisgill, the General Manager, Sir Guy Granet, told in his evidence at the second enquiry of the action the company had taken in respect of Sir John Pringle's recommendations with regard to Rule 55, in the Hawes Junction report. This statement is of historic interest in the art of modern signalling. Sir Guy Granet said: " You will remember, Sir, that most of the recommendations made in your report had reference to suggestions for minimising the effects of accidents after they had taken place, and very important suggestions they were, but my Board, after very carefully considering your report, came to the conclusion that, beyond what you had recommended, it was very desirable to see whether it was not possible to take further steps to prevent the occurrence of accidents, or at any rate to make it more improbable that they should occur. You will remember that in the first accident it was admitted that it had occurred through two causes, both failures of the human element, namely: first, the momentary forgetfulness of a signalman, a man of the highest character and record, who forgot that he had left two light engines on the road and subsequently admitted the express into that section; and secondly, owing to the failure of engine drivers, also men of the highest record, to observe the provisions of Rule 55, under which they ought to have reminded the signalman of the presence of these light engines in the section. That source of weakness having been revealed, it was recognised that there were places on the line where it was possible, either through physical causes or possibly through density of traffic, for a signalman to forget the existence of a train standing at signals in his section, and so admit another one into it. Accordingly a survey of the line was made, and it was decided that in over 2,000 places the circumstances were such that it would be desirable to install apparatus for correcting that tendency towards human error, and thereupon my Board made an order that apparatus should be provided at these places, and for the work to be put in hand at once. The apparatus decided upon was of a two-fold character. First of all there was the provision of track-circuiting and electric locks which has a two-fold effect. It has the effect of giving the signalman in his cabin a visible signal that there is a train in his section, and it also has the effect of preventing him, by means of electric locking, from improperly lowering his signals to admit a train into his section. Then, in addition to that it was decided to put in what is known as the 'Rotary Interlocking Block.' This is a device which protects the other end of the section, or rather the section in the rear—it prevents the signalman in the rear from pulling off his signals and admitting a train into the section in advance until any train in that section has passed out of it. Well, in order to do that work, my Board immediately set aside, as a first instalment, the sum of £100,000 over and above the ordinary expenditure for maintenance, renewal, and improvements, and ordered the work to be taken in hand at once, and that work has been proceeded with ever since as fast as possible. It cannot all be done at once: one obvious reason being the rate at which the locking of the signal lever frames can be altered, or added to, because the alterations in the locking cannot be done when traffic is about. Therefore, the whole of the work practically has to be done on Sundays; but special gangs have been put on, and have been continually at work at this since the order of the Board was given, with the result that we have today completed 374 track circuits and 379 Rotary Interlocking Block installations. That leaves still to be done 500 track circuits and 900 Rotary Interlocking Block installations. I think, Sir, you have seen some of the work. I believe it is thoroughly satisfactory, and I believe that we have gone considerably beyond what any other railway company has done in the use of these devices."

It can be truly said that the Hawes Junction accident did for track circuiting what the Armagh disaster of 1889 did for block working and automatic continuous brakes.

Illuminated Diagrams

The introduction of track circuiting was accompanied by the use of various forms of track circuit indicator mounted on the instrument shelf of signal boxes. The majority of these had relatively large mechanisms and provided a very prominent indication; but as the use of track circuiting increased, it happened that there were many track circuits to be repeated in signal boxes and so gradually the illuminated track diagram was developed. Among earlier installations, one of the most spectacular was that at Camden Junction, London Electric Railway (fig. 22) equipped with complete track circuiting, and illuminated diagram ; this

Fig. 12 Deal Street, Manchester—London Midland & Scottish Railway

interlocking, put into service in 1924, was the natural sequel to the earliest power boxes on the London Tube railways which must have been among the first, if not *the* first signal boxes in which the signalmen never saw any trains at all. It is perhaps fitting that the spectacular Camden junction should have become in recent months the site of another striking development in railway signalling technique, to which reference is made later in this paper. Reverting however to the first power interlockings on the London Tube railways, while the practice involved, of permitting a signalman to work entirely to an illuminated diagram and not see any actual trains, was considered very revolutionary at the time, and could be accepted on a railway where the entire traffic consisted of multiple-unit electric trains, there would then have been little chance of its acceptance on main line railways where it was considered essential for the signalman to see all trains at some time during their passage through his area, to observe the tail lamp, and thus be certain that no break-away had occurred. At that time track circuited areas were very limited in extent, and while track circuits in a power interlocking would provide the necessary protection, and detection, in the case of a break-away in the track circuited area, the train would almost certainly have travelled long distances through a non-track circuited area before entering the power interlocking, and thus the precaution of seeing the tail lamp was, at that time, considered just as essential as if the interlocking itself were a manual one.

Increased Security in Power Interlockings

In Great Britain development was retarded during the period of World War I, but when the time came for post-war developments, the power interlockings began to take on a more elaborate form than had been seen hitherto in this country. The use of track circuiting enabled facing point lock bars, and the means for actuating them, to be dispensed with, and although some of the stations re-signalled in the early "twenties" were large and complicated, the actual locking frames concerned were generally smaller than plants of comparable size installed before the war. On the other hand, traffic requirements in some of these post-war installations demanded the signalling and interlocking of a large number of alternative routes, and the actual mechanical locking mechanisms became exceedingly complicated. In general, the areas controlled could still be seen from the signal boxes concerned, though the introduction of colour light signalling was accompanied by visual indication of the signal aspects being provided on a display board behind the levers, where visual indication of the lie of each pair of points was also provided.

What might be termed the original form of power interlocking machine reached its climax in the large all-electric installations on the Southern, London Midland and Scottish, and London and North Eastern Railways put into service in the nineteen-twenties. Not the largest, but certainly one of the most complicated and most intensely locked was Cannon Street, Southern Railway, where the number of alternate routes involved an exceptional amount of conditional locking. The way in which economy had been made in frame size and cabin space can be appreciated by comparison of the Cannon Street and London Bridge interlockings with Glasgow Central as installed in 1908.

Location	Signals	Points	Working Levers	Total No. of Levers	Ratio: *Working Levers* / No. of Sigs. & Points
Glasgow ...	253	112	338	374	92·7
Cannon Street	89	79	131	143	77·9
London Bridge	219	148	298	311	80·9
Deal Street ...	107	77	99	107	55·6

The number of signals and points total up to 365 at Glasgow and 367 at London Bridge and yet the total number of working levers at the latter station is 40 less, due to the elimination of separate levers for the facing point locks. At Deal Street and Victoria West Junction, Manchester, L.M. & S.R., still further saving of space was effected by the use of push and pull levers for a number of signals, and by selection (see fig. 12).

The Inauguration of Control

At this stage in the history of power signalling, the signal boxes and their equipment were fulfilling essentially the same functions as those hitherto provided by mechanical interlockings.

The use of power had, in certain cases, enabled a number of boxes to be dispensed with; the manual effort required had been reduced, and the introduction of complete track circuiting had provided important additional safeguards. But the men in the boxes continued to work in much the same way as of old, relying in many instances on the bell code for communication with adjoining boxes, while in areas where a number of power boxes were adjacent to each other block working, as such, had been dispensed with, and various systems of train description had been installed. The regulation of traffic was the responsibility of signalmen, using the time-table as their guide when questions of priority, or trains running out of course had to be dealt with. Consultation between adjoining signal boxes was made by telephone, and only in cases of extreme emergency, such as a major accident or other circumstances involving complete derangement of train services, was there any overriding guidance for signalmen.

While it was generally felt that resignalling would improve safety, would enable traffic at individual stations to be handled more expeditiously, and would reduce operating costs by enabling a number of boxes to be dispensed with, it is probably true to say that there was not at that stage any widespread conception of a general improvement in the *control* of railway traffic on the broadest basis.

Simultaneously with the wide introduction of track circuiting on the Midland Railway, following the Hawes Junction accident, the Chief General Superintendent of the Midland, Mr. Cecil W. Paget, introduced the Control System for the regulation of the working of freight trains. Although the name "Control" was given to it at the outset, it was in the first place little more than a system of reporting train movements to a central office at Rotherham. With the systems of communication in operation in the first years of the twentieth century it was quite a difficult job to find out exactly where trains were—if they were running, or held up; and Mr. Paget's elaborate system of reporting brought information as to the whereabouts and loading of trains to a central point, from which action could be taken if necessary to meet congestion, or other forms of delay. Without such information it was not possible for the senior operating authority to pin-point any troubles that were occurring at any particular time on the line.

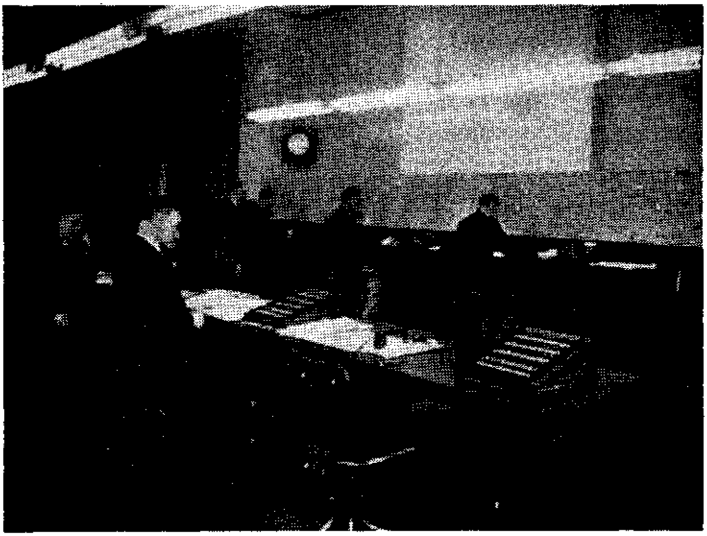

Fig. 13 District Control Office, Stoke-on-Trent—L.M.S.R.

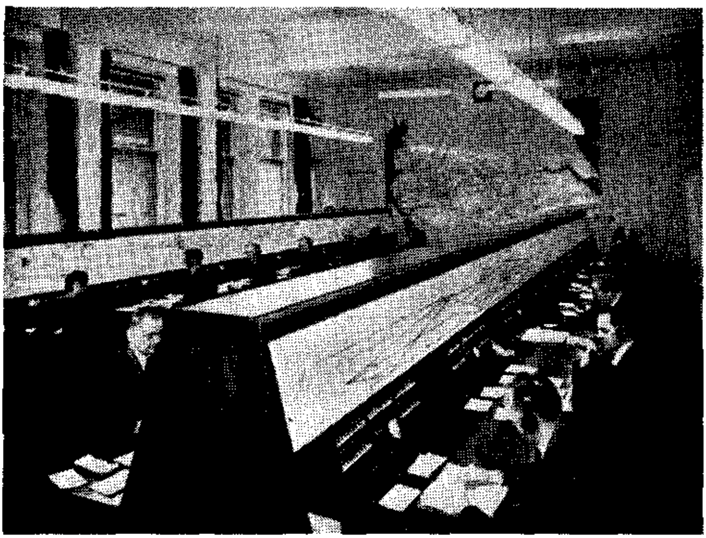

Fig. 14 Divisional Control Office, Manchester—L.M.S.R.

Once the means was established of providing information as quickly as possible the basis of control was established. Instructions could be sent to signal boxes from the central control office, in which latter the " picture " of train movement as a whole was constantly available. The state of affairs on the Midland Railway when the control system was first put into operation defies description ; for while passenger trains were run closely to their advertised times, the delay and congestion in the handling of freight was so severe and so widespread as to be almost intolerable. There were times indeed when freight trains never turned a wheel during the whole period that the enginemen were on duty. The system of reporting introduced by Mr. Paget, and the measure of control it enabled the central office to exercise proved an outstanding success ; from extreme congestion the Midland Railway was able to move its traffic with reasonable speed and efficiency, and of course the operating costs were greatly reduced. In time this system was extended to cover the whole main line network of the Midland Railway, and it was applied also to through express passenger trains. When the amalgamation of the railways took place in 1923, the Midland system of control was extended to cover other railways that came within the London, Midland and Scottish group. Photographs are reproduced herewith of the Control Offices at Stoke-on-Trent, a district office (fig. 13), and Manchester, a divisional office (fig. 14).

" Control " became gradually established and appreciated as an authority to which station masters, signalmen, or others could refer for guidance in the event of unusual circumstances, while reciprocally " Control," with the broad picture before them of operating in an entire district could, if necessary, give special instructions to any point. It is, however, very rare for Control to step in and give specific instructions to individual signalmen, save where workings of exceptional priority are involved. In the hour-to-hour handling of traffic there is just that time lag in the build-up of the picture at " Control " that precludes any immediate " butting-in "—as it were. Opinions have varied in the past among operating men as to which is the best way to record train movements in a control office. Prior to the nationalisation of the railways, some sections were using a development of the original " Paget " scheme whereby the times at which trains passed the reporting points were recorded on sheets, and other

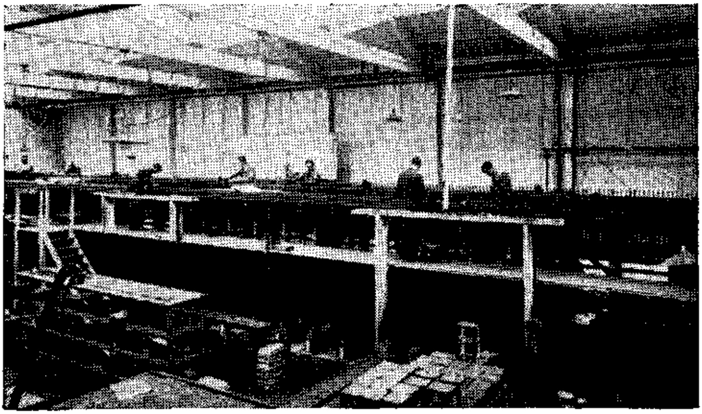

Fig. 15 London Bridge Locking Frame under construction

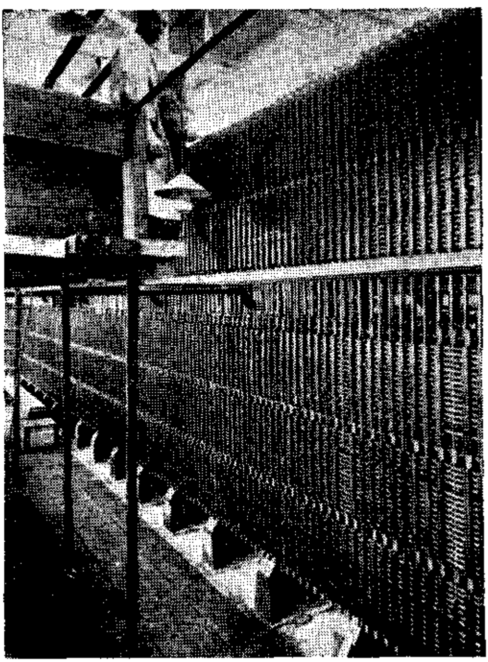

Fig. 16 London Bridge under construction showing locking mechanism

sections were using a graphic system of recording whereby the paths of trains were plotted on special graph paper. In the case of graphic recording, it is claimed that from the very nature of the record that is being made, minute by minute, the controller is in a better position to help signalmen ; he can see the traffic position more clearly, can anticipate delays, and take steps to overcome them. An example of this that comes to mind is the case of a fast train closing in on a slow one ; from the graph record an expert controller could judge how far the slower train can be allowed to proceed before side-tracking is necessary to avoid delaying the faster train which is following.

The Elimination of Mechanical Locking

Earlier in this paper the Author referred to the intensity of locking on some of the frames installed in the mid-" twenties." The design of the mechanisms was a difficult job in the first place. Numerous artifices were used to economise in space, by the combination, or partial combination of certain conditions ; but the difficulties experienced in the original design came to appear relatively slight in comparison when the time arrived for certain extensive alterations to be made to the locking, which latter were dictated by revised traffic working requirements at one of the stations concerned. Moreover frames of the size and intensity of locking as London Bridge required a high degree of precision in manufacture and erection ; great care was needed in alignment and levelling in order that the miniature levers, actuating many locking bars, should move easily (see figs. 15 and 16). It was to obviate these difficulties—in facility for alteration, and of erection—that the first frame with electric, instead of mechanical lever interlocking was designed, and put into service at North Kent East Junction, Southern Railway in 1929 (fig. 17).

This development, important though it was on technical grounds, did not involve any change in operating methods. The levers were still positively locked when conditions prohibited their clearing ; to the signalman it was obviously of no concern whether the lever was locked through the agency of a mechanical *enclenchment*—to use that highly descriptive French word, or through a de-energised electro-magnet. The result was the same. The lever could not be pulled. The integrity of the electric lever interlocking was maintained by encasing the magnets in sealed boxes. But the elimination of the mechanical locking

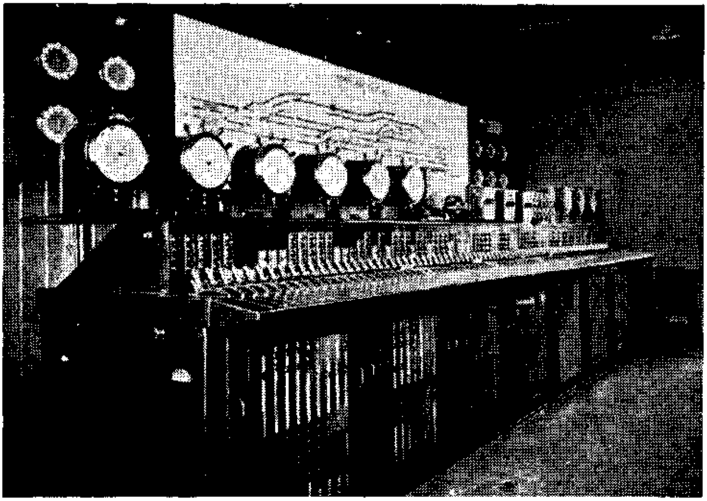

Fig. 17 North Kent East Junction—Southern Railway

Fig. 18 Waterloo—Southern Region

brought one fundamental operating advantage: there was no longer any necessity for the levers to be arranged in one continuous row. The frames could be built in two or more sections so disposed as to use cabin space to the most economical extent possible. The signal box at Waterloo, Southern Region, provides an excellent example of this (fig. 18).

The next step in the development of electric interlocking saw the elimination of the actual lock on the lever. Instead of releasing an electric lock, the circuits for signal and point control were arranged to energise a control relay, and it became possible to replace the robust lever and its attachments by a simple thumb switch. Although this system provided the highest degree of safety in operation it involved one radical change in principle at which British railway operating officers generally looked askance; it was now possible for a signalman actually to operate the switch controlling the clearing of a signal, or the movement of a pair of points, when that function, in fact, was locked. It is true that the relays would prevent any response to the signalmen's action, but this one feature cut so deeply across established practice as to raise some scepticism as to the wisdom of adopting it. The system of relay interlocking, as it is now so well known, was pioneered by Mr. A. E. Tattersall, in what was then the North Eastern Area of the London and North Eastern Railway. It needed a great deal of courage and enthusiasm to do that, when so many signal engineers and operating men were outspokenly critical; but we should recall no less the enthusiastic backing Mr. Tattersall had from that great personality of the day, Mr. John Miller, who was then Engineer of the North Eastern Area, and the readiness with which the operating officers of the North Eastern area were willing to try out the new technique. The first installation to be put into service was quite small, and controlled the signals in the approaches to the swing bridge at Goole; but there soon followed the spectacular relay interlocking at Thirsk.

It is interesting to study this layout, in some detail, as it is as much a milestone in the history of signalling as Granary Junction, and indeed as those primitive, but epoch-marking contraptions of Sir Charles Hutton Gregory, Austin Chambers, and others of the great pioneers. The track layout at Thirsk is shown in fig. 19. Through the station and southward on the main line there are two running roads, with the additional facility of running loops, each about half a mile long, on both down and up sides. North

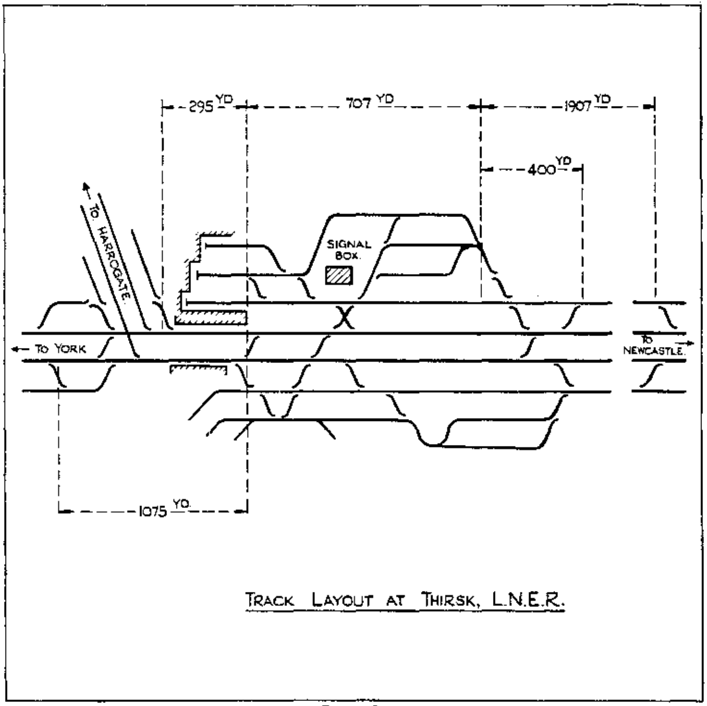

Fig. 19

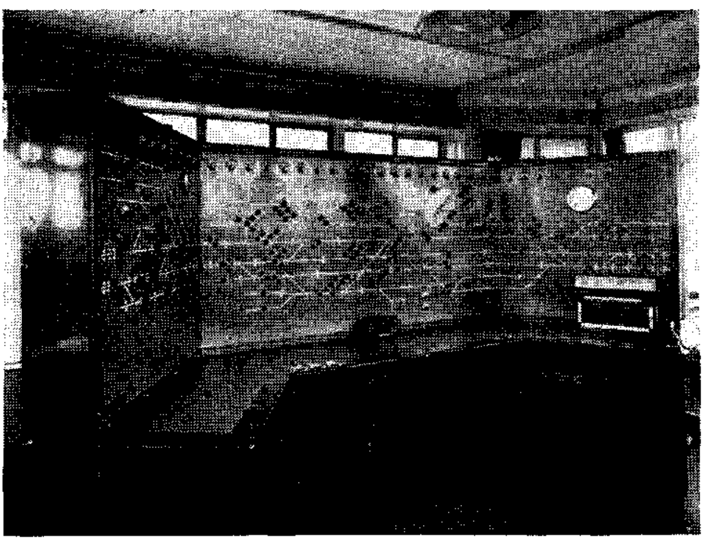

Fig. 20 Control Panel, Thirsk—L.N.E.R.

of the station there are four running roads, with nests of reception sidings on both sides of the line in the immediate neighbourhood of the station. Ample provision is made for crossing trains from fast to slow roads, or vice versa, on the four track sections ; the most northerly crossover roads controlled from Thirsk are nearly 1½ miles away from the signal box. If an all-electric interlocking of the orthodox type had been installed it would have required a power frame of 170 levers, with an overall length of about 24-ft. The relay interlocking actually used, quite apart from other features, is extremely compact. The control panel is no more than 12-ft. long and makes it possible for this extensive and complex interlocking to be readily operated by one signalman (fig. 20).

The design of this pioneer control instrument is of particular interest, when considered in relation to the traffic passing through Thirsk. There is not a great deal of shunting and the bulk of both passenger and goods traffic consists of through trains. The signalling arrangements on this account were designed on the route-switching principle, and by this means the work of the signalmen was greatly lessened. Trains passing through the interlocking area follow regular routes, or recognised alternatives, and these are duly signalled. To set up such a route the signalman operates only one thumb switch, and this action sets all the points concerned and clears the appropriate signal. In one case no less than 14 pairs of points and one signal are concerned, and the whole route is set up and signalled in six seconds from the operation of the thumb switch. The number of these through routes is relatively few, and it was found possible to mount the thumb switches concerned on the vertical panel whereon the track layout is displayed, each thumb switch being placed near to the signal controlling entrance to the route in question. The existence of alternative routes makes it necessary to have more than one thumb switch associated with most of the signals, and some of the shunt signals have no fewer than six thumb switches. To permit of the setting-up of unusual movements, that are not signalled in the system of route switching provided, a set of 35 thumb switches is included on the control panel for the individual control of every pair of points in the interlocking area. In passing it is interesting to recall that route switching as a means of reducing lever movements was first used in this country on the Great Western Railway at Winchester in 1922, and later in the large interlocking at Newport. In both cases, however, the principle was incorporated in a power frame and the interlocking between levers was mechanical.

Developments in Relay Interlocking

The principle of relay interlocking, combined with route switching and a control panel, has since been developed in detail, and while nearly all the British examples put into service before the outbreak of World War II were to be found in the North Eastern Area of the L. & N.E.R. it now seems probable that all large interlockings included in the British Railways Modernisation Plan will be equipped with relay interlocking and control panels, though the actual systems used will no doubt differ in both principle and detail. There is no finality in the field of signal engineering design.

Earlier in this paper, reference was made to the original power interlocking at Camden Junction, London Electric Railway. This junction has recently been resignalled incorporating the system of interlocking that was inaugurated on London Transport at Ealing Broadway some years ago. But all the traffic at Camden is " through "—no trains terminate in the area indicated on the accompanying diagram (fig. 21)* and to relieve the signalman of actual switching duties, an exceedingly novel system of automatic control has been introduced. There are many interlockings in this country where arrangements are made for automatic working at certain periods of the day ; but these relate to junctions where connecting traffic with the main line ceases entirely during the period that automatic working is in operation ; the moment any diverging, or converging movements are required the signalman takes over and automatic working is suspended. But, with the present arrangements at Camden, the normal way of working this intensively used junction is automatic ; the passage of trains over the four diverging junctions is controlled by the train description circuits, and movements at the four converging junctions are controlled on a " first come, first served " basis by the occupancy of the track circuits by the trains.

Arrangements are included, however, to provide for certain emergencies in the event, for example, of a train being wrongly described, or of its becoming necessary to alter the routeing of a train. Then the signalman must take control until such time as circumstances favour the restoration of automatic working. But while an installation such as this (fig. 22) can be considered

* See Inset Sheet No. 9

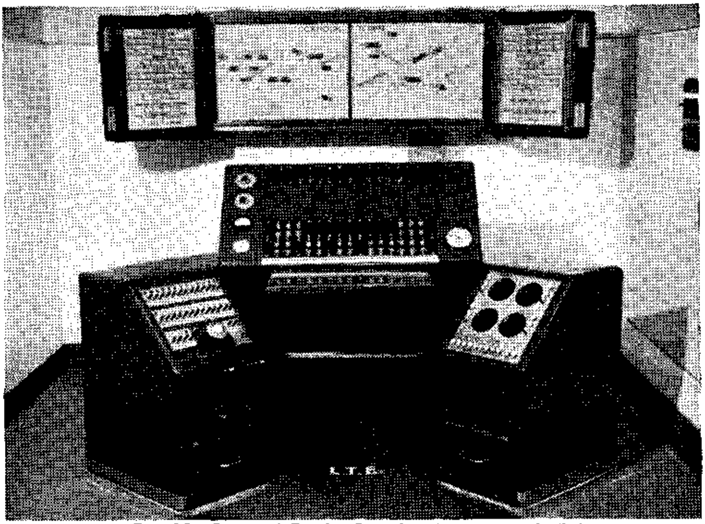

Fig. 22 Control Desk, Camden Junction—L.T.E.

truly prophetic of some of the things to come, and the nearest approach to complete automation in railway traffic control that has yet been seen anywhere in the world, the conditions are very favourable for such an installation on the railways of London Transport where there is complete uniformity in the type of trains, their speed and their brake power.

The interlocking at York, brought into service in 1951 is of special significance, not merely as the largest single interlocking plant ever put into commission, either in this country or anywhere else in the world, but from the part it has played in revolutionising freight train operation in the York District of the North Eastern Region. During the development of relay interlocking in the " thirties " it was realised that there was no technical limit to the extent to which signalling control could be concentrated in one box ; but opinions were sharply divided, both among signal engineers and operating men, as to the desirability of such concentrations. And, while North Eastern officers generally favoured one large signal box, at Doncaster, just over the boundary to the South, a large relay interlocking with two boxes was installed in 1949.

At York the functions controlled are as follows :—

294 signals, with which are associated 53 route indicators and direction indicators.

330 points.

825 routes.

From the viewpoint of a signal engineer, York is no more than a greatly enlarged version of some of the smaller relay interlockings that preceded it in the North Eastern Region; but certain features were included that from the operating viewpoint were novel, and which point clearly to what can be done in the future. Foremost among these features was the remote control of the entrance and outlet of one of the six "special class" motive power depots in the country. As an operating man once said: "Under normal manual signalling methods the entrance and exit from a large locomotive depot is regarded as a responsibility second to none. The customary technique is full of hand signals from signalmen to drivers and two-way conversations—both co-operative and perverse—between drivers and signalmen." To regulate such an inlet and outlet, where there are, on an average 210 movements inward and 210 outward in the 24 hours, and which can rise to 270 movements in each direction at peak periods, by remote control, might indeed seem venturesome. But it has been most successfully done. One factor that contributed to a large extent to the success of this remote control scheme, within the general scheme of York, was a small though significant rearrangement of the track layout (fig. 23)* which permitted of parallel movement of locomotives into and out of the depot and the inclusion of a small fan of double ended sidings which were made available for the sorting of outward engines. It was regarded as of outstanding importance that the signalmen at York should be able to exercise selection in the order in which engines left the depot, and this enabled instructions to be given for certain engines to be held back in the depot in the event of their not being immediately required, due to late running, when their presence in the station area would cause unnecessary obstruction. The statistics of operation show clearly to what extent things have improved, while from his many observations of working in the signal box the Author can speak of the care and efficiency with which liaison between the motive power running staff at the shed and the signal box is maintained.

But, as with the Midland Control system introduced by Mr. Cecil Paget, so with York, it is in the direction of freight train operation that the most spectacular improvements have been realised. The York District is an area that extends from the city itself, with its extensive marshalling yards, to Doncaster, to Scarborough, to Northallerton—to mention a few of the further

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* See Inset Sheet No. 9

points—and in 1950 it was stated that 75 per cent of the freight train delays in the district occurred at York itself. Between 1950 and 1952 however, the freight train speed in the district increased by 16 per cent and the freight train hours decreased by 20 per cent. York was no longer a bottleneck. Even amid winter fogs, which so beset the district, it has been found possible to despatch freight trains southbound from York at more frequent intervals than the manual block sections on the lines to Selby and Church Fenton can handle them. Although one can do no more than hint at the financial economies that are resulting from such improved working, it is clear that a reduction of 20 per cent in the number of freight train hours in a district handling such a volume of traffic as that passing through York must be causing favourable repercussions in many aspects of operating, in better working of train crews, and in much increased locomotive mileages per day.

The Possibilities of C.T.C.

The benefits derived from the concentration of control in a busy and complicated area, though one that is geographically compact are capable of just as effective realisation in more extended, though equally critical areas, where, maybe, a bottle-neck section may cover some 15 to 20 miles of main line. The prohibitive cost of cable has, up to the present time largely precluded the bringing of such areas under the control of one signal box, though the rapid progress of C.T.C. in America during the war had naturally directed attention towards the way in which signalling technique could be used for traffic control purposes. It was no doubt the wartime progress in C.T.C. that was in Mr. Tattersall's mind when he made a prediction, in the course of a paper he read to the Railway Engineering Division of the Institution of Civil Engineers in November 1942. Commenting on Control practice, as developed from the original Paget system on the Midland Railway he said: "The success which has attended traffic control systems prompts the question: why should such a system stop at traffic control? Why not extend it to the signalling system? From an engineering point of view that is quite possible; the only limiting factor is the financial one." He was convinced that the trend of signalling development is in this direction and that such development will be hastened by post-war requirements.

" It will be appreciated that signalmen are in a way traffic controllers also, but if their sphere of control can be largely extended, then their duties approach more and more to those of the person or persons in charge of traffic-control centres, and combination of the two posts appears to be the ultimate solution."

Where the graphic method of train recording in the control office has previously been used, the combination of controller and signalman under some scheme of C.T.C. would be facilitated, since the automatic graph recording apparatus usually incorporated in C.T.C. schemes would produce, automatically, the same kind of record that the controller formerly built up for himself. Passage of the trains at reporting points would be automatically plotted on the graph and all the controller (or signalman) would have to do in plotting a chart would be to join up the automatically plotted points by straight lines.

Finance has not been the only consideration. In America, and in countries of the British Commonwealth C.T.C. has been most successfully applied on long stretches of single line, where trains are relatively few. The density of traffic on many stretches in this country to which the application of C.T.C. might be considered is such as to make the time of sending the codes a predominating factor. The stretch of line indicated in fig. 24 could be considered as typical of some 20-mile bottlenecks on British Railways. It is the kind of section where the signalmen at each small interlocking, at the points A to H, cannot be expected to have an overall picture of traffic, and they are apt to initiate movements in which slower trains may delay faster ones. Many examples of what can happen will come to mind from a study of this diagram, and the traffic situation is changing too quickly for District Control to be able to help. From the view-point of signal engineering there is nothing to prevent the entire area from being worked C.T.C. But, until recently, the most rapid coding required 1½ secs. for transmission of a control code and another 1½ secs. for the indication code to be received back and registered on the diagram. It is true that the control machine could be sited mid-way, and thus codes could be sent leftwards and rightwards simultaneously. Still greater flexibility could be obtained by dividing the lefthand and righthand sections again, and transmitting to the first half of each by direct coding, and to the more distant sections by carrier codes. By this means four codes could be in process of transmission to or from the control machine simultaneously. Even with

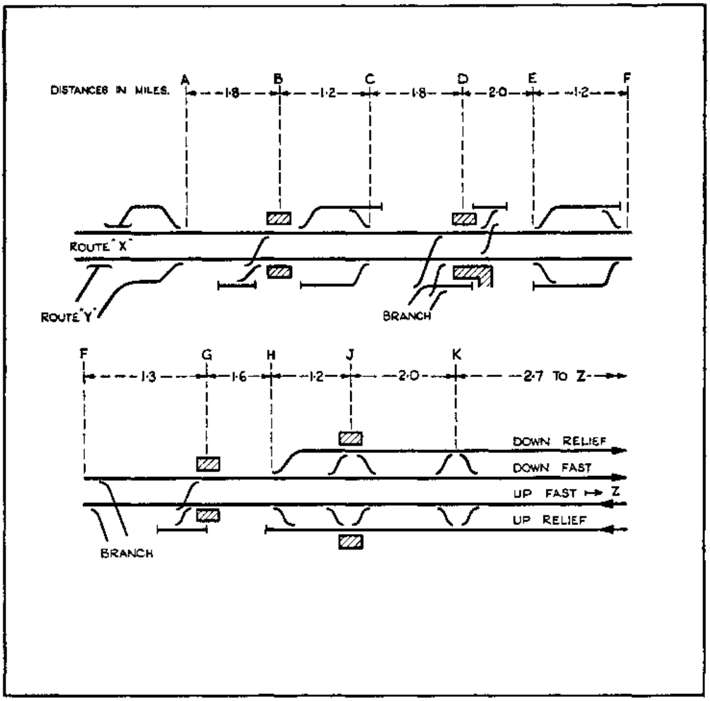

Fig. 24

this, however, the time taken to transmit the codes would seriously limit the capacity at times of the greatest pressure. A remotely controlled interlocking could no doubt be designed to cope with traffic normally scheduled, and to provide a margin for recovery ; but we are all too well aware of those hectic occasions when through some delay a succession of trains is all bunched up, following each other block and block, and then, when extreme flexibility was most needed, the machine would almost certainly be hamstrung by the time the codes would take to come through.

Today the science of electronics is available to assist the signal engineer in making available to operating staff the fastest method of control yet devised, and it is now possible to install apparatus capable of handling 30 control codes, and 60 indication codes per second. It will be appreciated that with such rapid means of control, needing only two line wires, the extent of a remote control interlocking is no longer constrained by distance or geographical complexity. With means now becoming available for overcoming the disadvantages of C.T.C. coding time, there remains, however, one difficulty which is found alike on main routes carrying some of the fastest and heaviest traffic, and the quietest country branch—that is the existence of level crossings. On any route where traffic is considerable, it seems essential to retain a man on the spot ; no matter what warning devices were installed there is always the risk of some road user attempting to "jump the lights." One could hardly face the risk of dropping a lifting barrier, or closing the gates in the immediate face of an oncoming vehicle.

Into the Future

Schemes under the vast modernisation plan for British Railways are, as yet, barely beginning to take shape ; but in looking forward to the new era we must surely aim at very much higher standards of punctuality. What can be done by the concentration of control at key points has already been demonstrated at Thirsk, York and elsewhere. How a concentration of control over wider areas could be achieved with relative economy and the utmost flexibility in operation has been indicated in this paper. The Author envisages a time when a heavily worked main line of 150 to 200 miles could be operated from no more than a dozen interlockings, with direct wire control for functions within, say, a 2-mile radius of the cabin and electronic remote control for all functions beyond. The benefits in operation would be immeasurable. Hitherto the peculiar deliberations of country station working in Britain have been quoted as precluding the wide use of C.T.C. in one form or another ; but if the movements in and out of York Motive Power Depot can be regulated by remote control, surely comparable tactics would be adequate in dealing with traffic at Great-Puddlecombe-on-the-floss !

Conclusion

In conclusion, the Author wishes to express his thanks to Mr. A. P. Hunter, Chief Operating Superintendent, North Eastern Region, to Mr. R. Dell, Signal Engineer, London Transport Executive, and to his colleagues in the Westinghouse Brake & Signal Co. for assistance in connection with the paper.

DISCUSSION

Col. G. R. S. Wilson, in opening the discussion, said the paper was of special interest to Inspecting Officers of Railways because they were concerned almost entirely with the safety of traffic, in which the efficiency of the railway signalling was of such very great importance. The author had traced the history of power signalling in the United Kingdom from the early days at Granary Junction to the present time, with a glimpse into the possibilities of the future. Colonel Wilson said that he personally came into the story when electrical interlocking was well established, when the miniature lever frame was predominant in this country in new parts of signalling installations, and when pioneer installations were being made, such as Thirsk and Goole, he remembered Thirsk extremely well.

He had enjoyed the very interesting slides shown by the author of large and small power frames, old and new, and the paper which had recounted the interesting development of track circuits and power interlocking, and all the functions in which trains could take a large part in their own protection. Referring to the case at Hawes Junction in which a serious accident occurred because two extremely reliable men in independent positions both failed, Colonel Wilson said that cases of that kind in the absence of complete track circuiting did happen, even today. He recalled an instance at Penmaenmawr six years previously, when a light engine was overlooked on a running line and a following train accepted. A complete installation of track circuiting had since been put in there.

He quite agreed with the author that there was no finality in railway signal engineering. The introduction of power interlocking of levers was, to a certain extent, due to the difficulties of mechanical interlocking in large power frames. At the time that it was first introduced, it was viewed with some doubt by the Inspecting Officers, but the signal engineers proved to them that there was no greater risk of false lever movements than with the mechanical interlocking. Similar fears were experienced when relay interlocking with the free turn-button switch came into operation; but once again, after study of the designs, explanations by the signal engineers, and examination of relays, workmanship and so on, it was proved that there was nothing to fear. Thirsk dated from about 1933 and had gone on for 23 years without a dangerous failure. No doubt there had been maintenance troubles, as with all complicated pieces of apparatus. There was a derailment there two years ago when points moved under a train, but as Brigadier Langley pointed out in his Report, the accident had nothing to do with the relay interlocking characteristics.

Inspecting Officers sometimes found new developments a little difficult to follow, but it was so important for the Railways to carry their traffic with the least possible expenditure, that any proposal to enable them to do so would have the Inspecting Officers' very sympathetic consideration. They had great confidence in the competence and integrity of the railway signal engineering profession in all its grades.

Mr. E. G. Brentnall said that he was fortunate to be intimately concerned with the early interlockings at Thirsk and Goole. There were considerable comments on the installations at the time, but to receive criticism did not necessarily mean that one was wrong. Thirsk route relay interlocking was brought into use in 1933. It was now 23 years later and it had taken that time before relay interlocking had become generally accepted in Great Britain. In the meantime, other things had gone ahead more rapidly. He thought that reference should be made to the part played by the manufacturers, who developed parts for relay interlocking and made it such a success. Relay interlocking would be the basis, in one form or another, of future signalling. There was the question of the coding of C.T.C. installations as such, or with interlocking located at various points and controlled over either one code over a limited number of wires or one wire for each function of other types of installation. The two types would both be used.

He thought the author had shown unusual pessimism regarding level crossings. With regard to jumping the lights, recent experience of crossings on the Continent showed that the tendency to do so occurred mostly when the signalman was on the spot. Where there were lifting barriers and a man was there to operate them, the motorists seemed to think that the man would wait for them. There were two methods of operating barriers—(1) by a man operating them electrically from some distance away, and (2) by automatic operation by the trains themselves over track circuits or treadles at a suitable distance from the crossing. Automatic operation was the most effective, because if remotely operated by the signalman, he had to have a view of the crossing, either a direct view or by other means, which was expensive and not thoroughly satisfactory. With automatic operation, time was cut to a minimum—on the Continent, 25 seconds for the fastest train. There could be regulated control, so that the time of 25 seconds was almost constant for any type of train. That might be because the difference in speed between the fastest and the slowest was not very great. With automatic operation, the method was to have half-barriers only, which blocked the side of the road where the traffic was approaching, but which left a space for a car to escape if caught on the crossing. It had been argued that motorists would try to get through when the barriers were down, but if they knew that a train would be there in 25 seconds, they would not be likely to run the risk. If one could have one type of control barrier and close it in the smallest possible time, that was the safeguard against jumping the lights. The future of crossings was in the possibility of the acceptance of lifting half-barriers. Admittedly, lines were not always fenced and for 150 years people had been used to heavy crossing gates, but as shown by relay interlockings, outlooks could be changed.

Mr. A. Moss said that the paper dated the extension of track circuiting from the Hawes Junction accident of 1910, but some people had appreciated its value before that and had applied it extensively. He was himself associated with the important installations, covering many pneumatic signal boxes and continuous track circuiting, constructed in 1906-1907 along the Guide Bridge widening of the former Great Central Railway main line approaching Manchester. In 1909, the London Road terminus also was equipped in that way. Other installations were made at Elsecar and Wath Yard where track circuiting was again extensively used with great success, as it was later elsewhere on the line, as at Immingham, with all-electric power signalling. The G.C.R. also had examples of intermediate track circuit controlled signals and at the Keadby lifting bridge an electric power box was opened in 1916 with track circuiting there and on the approach lines and 3-position upper quadrant semaphore signals, the forerunners of the multiple-aspect colour-lights of today. The work of those who built these installations, an important contribution to the evolution of power signalling in Great Britain, deserved to be remembered.

Mr. R. A. Pascall referred to individual push buttons on a route system as compared with multiple pushes with a type of installation such as Liverpool Street, and said that it would seem that in a box like Liverpool Street, where the multiple switches were arranged geographically on the diagram, it should be a good deal easier for a relief signalman to learn the box, than in a case where he had to learn his levers numerically.

Regarding lifting barriers, Mr. Pascall said that while serving in the Royal Air Force in North America during the war, he had seen a ramp that came up by mechanical means from the road, reaching a height of 1½-ft. or 2-ft., and he imagined that that would be fairly effective in stopping anything.

Mr. J. H. Fraser said he had been connected with several of the installations mentioned in the paper. In particular, he recalled coming to London with Mr. Tattersall to meet the contractors and to attend a demonstration of what was the beginning of the installation at Thirsk. The diagram shown in the paper was not quite correct, as the lines were widened at Thirsk during the war, so that there were four tracks right through. His only reason for mentioning it was to emphasise the point of how easily that alteration was made. The considerable alteration in interlocking involved had been made quite easily on the panel—much more easily than would have been the case on a power frame. What they did was to make a duplicate of the panel at the left-hand side and to alter the wiring which was all ready down below. He had recently returned from the United States where they had made some important strides in reducing the time taken by C.T.C. codes. The control codes went out and the indication codes came in, and he saw no reason at all why one should not think of signal boxes controlling very extensive territories.

Mr. T. S. Lascelles said that he found a paper of this kind particularly enjoyable. It should be noted that, in addition to the G.C.R., the L.S.W.R. had installed many pneumatic signal boxes, beginning at Grateley in 1901 and continuing at Salisbury, Staines and at and from Basingstoke to just below Woking before 1907, again with continuous track circuiting and many automatic signals. The Hawes accident, however, had given a great impetus to the application of track circuiting to manual signalling installations. The original pneumatic and hydraulic power systems arose from a wish to have something which a mechanical fitter could maintain and avoid bringing in the telegraph department, which then dealt with anything electrical on a railway. The hydraulic system, devised by Bianchi in Italy, and still widely used there, was produced expressly to enable long single line crossing places to be controlled entirely from the centre of the station by one person alone, and it proved very successful. Interlocking performed entirely by circuiting had been suggested very long ago, but for many years there was the fear that a correct interlocking effect might be taken for a failure and lead to ill-considered action ; actual locking on the levers or handles was thus felt to be safer. The C.T.C. idea originated in America as a logical result of the train dispatching system adopted much earlier from force of circumstances, and had paved the way for further developments. The new technique springing from it was finding increasing application in many places. There was now an important example of centralising the working of groups of junctions at Bologna, with automatic route setting by train describer, and a new very large signal box also controlling several junctions on approach lines, on similar general principles, was nearing completion at Frankfort. No doubt other instances of this would be seen before long.

Mr. J. F. H. Tyler referred to St. Lazare in Paris, where there was a C.T.C. panel associated with the railway control. There were rather different arrangements for the sections of control. Each man had a board about the same size as a C.T.C. control panel and they were arranged alongside the wall, and one of them was controlling the lines into and out of Paris. There was some talk at that time—in 1947—of extending the system, but he was not sure whether the idea had been pursued. The controller had to do many other things, for instance, to note the state of marshalling yards and sidings. Although he had been given a panel from which he controlled all the signalling in his section, he must be in the same room or very close to the people who deal with the engine working and the people who receive information from the yard ahead. He felt that it might be that if the panel was made big enough to accommodate the section control ahead, it would be sufficient. On the question of panels, Thirsk had four sections. In the large concentrated schemes which they were going to have, there would be perhaps fifteen or twenty similar sections, and alterations which had to be made were rather too frequent for the signal engineer's comfort. It could be that with large installations, very little time would go by without some alteration having to be made. It was, therefore, essential that, coupled with consideration of these large concentrated schemes, panels should be provided that were capable of alteration with the minimum of work.

The **Author** said that it had been a great pleasure to listen to the discussion and it was most gratifying to hear from Colonel Wilson that many doubts in the minds of Inspecting Officers over new ideas had been allayed during the course of time.

Replying to Mr. Brentnall on the subject of level crossings, he thought that many engineers had been a little pessimistic up to a point but would be heartened by what Mr. Brentnall had said concerning the methods which were being used to get over the difficulties. The idea of a fixed time, such as a 25 seconds interval, should certainly tend to compel the motorist to exercise due care.

The Author thanked Mr. Moss for drawing attention to what was an omission in the paper to cover the work that was done on the Great Central Railway, and as mentioned by Mr. Lascelles, on the former London and South Western Railway also.

Replying to Mr. Pascall, he thought that the question of whether single or multiple switches should be used should be left for the operating officers to decide as it was a contentious matter.

Replying to Mr. Fraser, he said he had deliberately shown the diagram of the Thirsk layout as it was originally, but he was aware that the station had been altered during the war. It was most interesting to learn how easily the alteration had been made because one of the things that had been said against panels was that they were very awkward to alter.

Replying to Mr. Lascelles, he said he noted the sharp line of demarcation between the signal and telegraph departments in the old days, when the signal department wanted something that their own fitters could handle, and were not, therefore, anxious to introduce electrical apparatus. That was why most of the earlier installations were of the kind they were.

The development of C.T.C. took place, in the first instance, in America and was a natural outcome of the train dispatchers and their code of practice. It was the life-belt of all operating men on American railways. In most cases, C.T.C. was installed with the first real signalling they had on any of those lines. Gradually, we came to time interval block and then to absolute block. They went straight from nothing at all to C.T.C.

Replying to Mr. Tyler, he was aware of the interesting installation on the S.N.C.F., but had no further information concerning developments.

Dealing with the question of the combination of the duties of signalman and controller and the fact that the controller, given a C.T.C. control panel had to have a good deal more information than the position of trains up and down the line, and that other people ought to be in the box near him ; that actually did occur. In the box at York, there was a locomotive and rolling stock controller in the box all the time.

The **President** said that they had heard what signalling people did a generation or two ago and what could be done today by electronic means, and he was sure that in the future the problems would be solved both on the technical and on the operating side. He proposed a very cordial vote of thanks to Mr. Nock for his excellent paper, which was carried with acclamation.

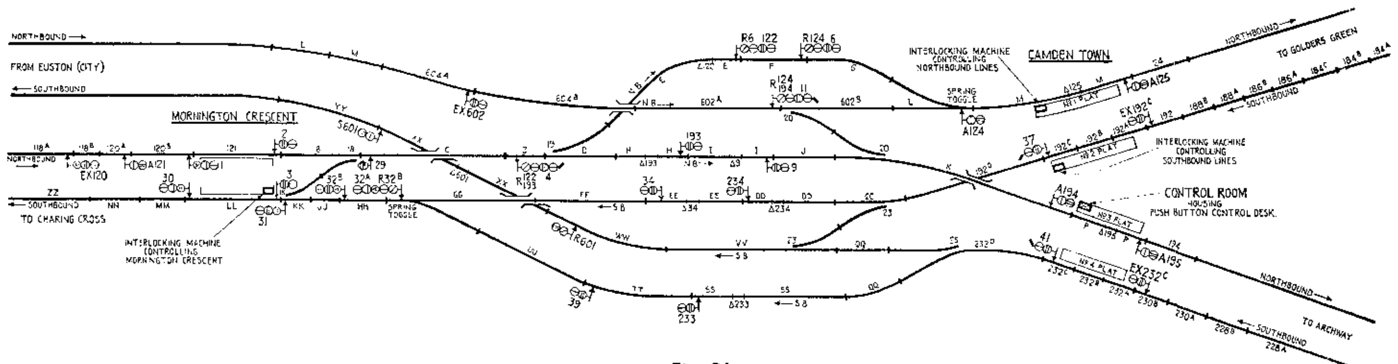

Fig. 21

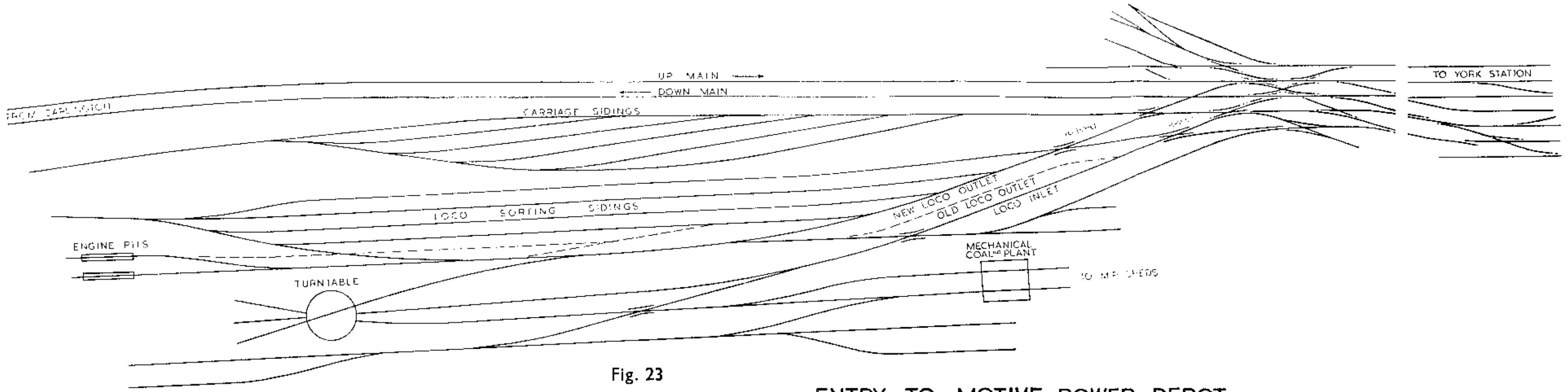

Fig. 23

ENTRY TO MOTIVE POWER DEPOT

YORK.