The President then invited Mr. W. H. R. Webb to read the following paper :—

Some Notes on Electric Interlocking.

By W. H. R. WEBB (Member).

(Diagrams—Inset Sheets Nos. 12-15).

Considered in its broadest sense, interlocking is the foundation of the art and practice of signalling as we know it to-day. Briefly defined, interlocking is any means used to prevent the completion of some particular function except under predetermined conditions. This definition is of course a broad one.

The particular function referred to may be some act on the part of a signalman, such as pulling a lever, or it may comprise the operation of a particular piece of apparatus, such as a point machine or a relay. Expressed in non-technical language interlocking may be considered as a means used to prevent two events occurring simultaneously, and to compel sequential operation.

It would be beyond the scope of a paper such as this to give a comprehensive survey of all the means which have been adopted from time to time for this purpose ; but it has been the Author's aim to present in a simple manner some notes on the methods at present in use and the trend of future development in the hope that these may form the basis for a discussion. In order to preserve a logical sequence and for the sake of completeness a number of details have been included which may appear somewhat elementary, and for this the Author asks the indulgence of those already familiar with them.

The function of interlocking is two-fold. Primarily it is a safety device ; that is to say, it is for the purpose of preventing collisions or derailments. Its secondary function is to facilitate traffic movements. This distinction is made for the purpose of considering the methods employed, as means required to fulfil the primary object may be entirely unnecessary when only the secondary object need be considered. Considered in detail, the objects to be attained for the purpose of safety are :—

1. Prevention of conflicting train movements.
2. Insuring the integrity of the route during the passage of a train.
3. Checking the correctness of the signal indication displayed to the driver.

The requirements from a traffic point of view are in most cases individual to particular local conditions, but the following general principles are enumerated :—

1. The releasing of route locking as early as possible.
2. Speed of operation.
3. Ease of manipulation.

Prevention of Conflicting Train Movements.

Since the introduction of the first interlocking frame the fundamental principle of interlocking between the various levers controlling points, signals, etc. has undergone very little change, although considerable ingenuity has been shown by inventors in perfecting the details of the mechanical locking frame itself.

With the advent of power signalling and track circuiting other safety devices were added to the interlocking but these were in every case regarded merely as adjuncts to the mechanical locking itself, on which reliance was placed fundamentally for the prevention of conflicting train movements.

This is equally true of most present-day installations, although the means of accomplishing the locking have undergone some changes. The earliest power frames were provided with interlocking operating on the tappet principle, and various means, all more or less complicated, were employed to insure correspondence between the lever and the function to be operated.

Tappet locking, although perfectly satisfactory in service, suffered certain disadvantages from an operating and maintenance point of view. For example, it was necessary when numbering a large frame to consider not only the best numbering from an operating point of view, *i.e.*, the best grouping of points and signals for easy manipulation, but it was required also to consider the mechanical necessity of keeping the locking bars of reasonable length and of accommodating the locking in the space available. Furthermore, when locking changes had to be made a considerable amount of work was involved.

In addition to mechanical locking, the levers of these power frames were provided with electric locks operated by track circuits and also with similar electric locks operated by indication magnets, for the purpose of proving correspondence between the lever and the operated function. With the increase of power interlocking more and more reliance was placed on these electric locks, so that it was a logical development that eventually the interlocking between levers should also be accomplished by their use.

We shall use the term "electric lever interlocking" to distinguish this from electric interlocking in general.

Electric lever interlocking, besides overcoming the disadvantages of tappet locking mentioned above, has resulted in other improvements. The frame can be accommodated entirely above floor level, and the sections of the frame need not necessarily be fixed in a straight line.

Installation is simpler as the very accurate levelling necessary with mechanical locking is not required. In some cases the wiring of the frame can be done in the factory. This has particular advantages for frames to be shipped abroad, where skilled locking fitters would not be available for erection. The accompanying lantern slides illustrate some typical installations.

Let us now examine generally the methods used to obtain lever interlocking electrically.

The locking frame consists primarily of slides or miniature levers, each fitted with one or more electric locks, and each carrying a set of contacts for the control and selection of the various signal and point operating circuits. In addition each lever is provided with a set of contacts, usually of the rotary type, for the purpose of locking or releasing other levers.

This set of contacts fulfils the same function as the locking trough and tappets on a mechanically locked frame. The elimination of the locking trough has involved certain changes in design. In particular it has permitted the structure of the frame to be lighter and more compact.

The rotary contacts themselves next call for consideration. Interlocking contacts (*i.e.* those used in interlocking circuits) require to be set with greater accuracy than is necessary for contacts used only in operating circuits. This may be achieved either by providing a means for accurate adjustment of each individual contact, or alternatively by providing an increased stroke on the contact carrying shaft thus giving a greater travel between the various contact positions.

Interlocking Circuits.

Before considering the interlocking frame in further detail it is proposed to discuss briefly the circuits involved. Plate 1 shows diagrammatically the fundamental mechanical locks with the equivalent written circuits for electrical interlocking.

Figure 1 shows the standard symbols used to designate the various lever positions. The actual angular displacements of the lever or contact shaft corresponding to these symbols will vary with the practice of different makers, and will depend on the design of the mechanical parts of the frame. Figure 2 shows a typical circuit for the elementary case of a direct lock between lever 1 and lever 2. It will be apparent that whereas in most types of mechanical locking if 1 locks 2, 2 must of necessity lock 1 ; in electric locking this is not the case, and each lock and its converse must be treated individually. This feature can sometimes be utilised to provide special facilities by providing a lock while omitting the converse.

Assuming that 1 is to be released by 2, together with the converse of 2 backlocked by 1, the circuit would appear as Fig. 3. The case of both way locking is similarly illustrated by Fig. 4. Conditional locking is effected in a relatively simple manner as shown in Fig. 5. Here again the consequential backlock on lever 2 must not be overlooked. This will probably not appear in the locking table, but in many cases it will be found that the condition is already covered by either 1 or 3 locking 2 both ways. The complete circuit will then appear as Fig. 6.

It must be understood that the above circuits are typicals drawn to illustrate the principles involved. The complete circuits will have to be arranged to suit the arrangements of electric locks on the particular frame in question. For example, some frames are fitted with only one lock to each lever, this lock serving both for the purpose of lever interlocking, and also for track locking. Secondly, two locks per lever may be provided, one of which performs the function of lever interlocking, while the other takes care of track circuit locking, indication locking if used, and back locking. Yet a third variation is to provide two locks per lever, both of which perform lever locking and track locking, but one lock functions in the normal and normal indication position only, while the other performs a similar function in the reverse and reverse indication positions. The two former variations are illustrated on Plate II Figures 7 and 8 showing typical circuits for a signal lever, and Figures 9 and 10 showing typical circuits for a point lever.

It will be seen in the example shown in Figure 7 that the back lock on lever 6 occurs in the normal indication position of the lever, irrespective of whether this is caused by the dropping of 6TR or by lever 9 having been pulled. In Figure 8 due to the fact that two locks are employed the back lock due to a track circuit will occur in the normal indication position but that due to a lever will occur in the full reverse position. The necessity for lever 6 to be backlocked by lever 9 arises from rotation locking between 6 and 9, and is the converse of the condition " 9 released by 6 " which would appear on a separate circuit concerning lever 9. This rotation locking is an example of locking provided rather for traffic purposes than from considerations of safety, and is dealt with in more detail below during the discussion of a complete circuit.

Referring to Figure 9 it may not at first sight be obvious why lever 13 locks 12 in the normal position, while lever 6 locks 12 in the reverse position. The reason for this will be found by considering the reciprocal condition, which is " 6 released by 12," so that lever 6 cannot be moved until 12 has been reversed, after which the pulling of lever 6 must lock 12 in the reverse position.

As an illustration of the application of the above principles some examples have been chosen from the circuits used in the recently completed installation of electric interlocking at Manchester Central, Cheshire Lines Railway, which members have the opportunity of inspecting during the present meeting. Figure 11 shows the circuit for point levers Nos. 59 and 60, which may be identified on the plan Plate IV Figure 13.

An extract from the locking table for these two levers is as follows :—

Lever No.	*Released by*	*Locks in Normal position*	*Locks N & R*	*Backlocked by*
59	Nil.	56.57.58.61.	Nil.	4.14.60(125.126.w 92R.101R).75.
60	59	4.14.64.76.	Nil.	5.15.
74	Nil or 87 or 88	55(1.11.25.w.87N 88N) (2.12.26.w.87R). (3.13.27.w.88R). (48.49.w.89N). (44.w.89R).	87.88	(116.117.w.89R) (125.126.w.89N)

In order to check the circuits against the locking table it must be remembered that the locking appearing from the circuits will actually be the reciprocal of that appearing in the table. The locking for levers Nos. 59 and 60 reconstructed from the circuit diagram would appear as follows :—

Lever No.	*Released by :*	*Locked by :*	*Backlocked by :*	*Locked both ways by :*	*Locked by tracks :*
59	Nil.	56.57.58 61	4.14.60.75 (125.126. w.92R. 101R)*		174.175.176
60	59	4.14.64.76	5.15	75	175.176.178

Figure 12 shows the locking for a signal lever No. 74 shunt signal. When decoded this will read :—

Lever No.	*Released by :*	*Locked by :*	*Backlocked by :*
74	Nil. O.R. 87 O.R. 88	55. (1.11.25.w.87N.88N) (2.12.26.w.87R) (3.13.27.w.88R) (44.w.89R) (48.49.w.89N)	(125.126.w.89N) (116.117.w.89R) track circuit 168.

Referring to the locking for lever No. 59 marked * above, this is an example of locking introduced for traffic purposes rather than purely for safety. This piece of locking is intended to prevent a passenger train from the Up B. Route being routed over 92R.56R. or 92R.59N. This move is only permitted for a slow speed shunt move, *i.e.* a move made with points 101 normal.

Referring again to the circuit for lever 59 it will be seen that before the lock can be freed, not only must lever 58 controlling the trap points in " B " Road Middle be normal, but the circuit is also taken over the point detection relay to prove the position of the points themselves. This will be referred to later when considering generally the subject of correspondence between points and lever. In the installation at present under consideration all points requiring to be set for trap protection are so proved. An alternative method of obtaining the same result is to electrically detect trap points in the circuits of the signals reading over the routes which the trap points are protecting.

In this installation both facing and trailing points in the direct route of a signal are so detected, and the point circuit is such that unless the points and the lever are in correspondence the point detection relay will be de-energised.

A further point to be noted on this circuit is the provision of a " lock free " light for each lever. This is an indication light in parallel with the lock circuit which is illuminated when the lock is energised. This feature is provided as an assistance to the operator both for showing when levers are free from track or route locking and also for indicating when the lever is free of locking by other levers.

Insuring the Integrity of the Route.

At a mechanical interlocking the safeguards used to prevent points being thrown during the passage of a train are firstly facing point bars, which are of necessity of limited length, and secondly the spacing of signals in such a manner that a train is always under the immediate control of the signalman. Due to the mechanical locking the signal levers when reversed hold facing and trailing points locked ahead of and sometimes also in the rear of the signals concerned. Beyond this the responsibility rests with the signalman to protect the train against derailment.

By providing track circuits covering every pair of points a much more positive safeguard is provided, as these track circuits definitely lock the corresponding point levers. Where power signalling with complete track circuiting is provided this form of locking is universally used and is known as " detector locking," or " track locking."

The detector locking therefore takes care of matters while the train is actually passing over the points, but it is of equal importance to prevent any movement while a train is approaching ; that is to say during the time which elapses after a driver has accepted a signal and before the first pair of wheels has dropped the detector track circuit. This is usually accomplished by means of " backlocking " the signal lever. This backlock becomes effective in the normal indication (B) position and prevents the return of the lever to normal until such time as the points are held by detector locking. During this time the point levers are therefore held by the lever interlocking, and subsequently by direct track locking.

When the backlock on the signal lever is controlled by track circuits in advance of the signal the term " approach locking " is used. Sometimes the approach locking is applied directly to the point operating circuit.

Figure 14 has been drawn to illustrate the electrical means that may be used for the purpose of holding the route during the passage of a train. Theoretically the minimum length of the approach period V-W is a function of the braking distance. That is to say, the distance V-X should be such that if lever 1 should be put back in the face of a train approaching at V, the train can be brought to rest before reaching X. During this period the lever is backlocked. When the end of the route is reached, that is to say during the period Z-Y, points No. 3 are held by direct track locking. There remains the distance X-Y to be considered. This may be covered by extending the backlock on lever 1 to the point Y. In the case of a busy yard, this may unduly retard traffic movements. By providing sectional release route locking, the back-lock on the signal lever may be released at the point X, the points ahead remaining locked by the release route locking relays. The action of these will be explained later. Points No. 4 will now be free to be moved as soon as the train is clear of track circuit C.

In cases where sectional release route locking is to be installed care should be taken in preparing the tables of lever interlocking that no locking is provided which might defeat the object of the release route locking.

For instance, in the example shown, if lever 2 were to lock lever 4, as would be usual in mechanical practice, then in spite of the fact that points 4 had been freed by the release route locking relays when track circuit C picked up, actually they could not be pulled until track D was clear allowing lever 2 to be restored normal.

An example of route locking is to be found at Manchester Central on signal No. 127, the Home signal for the Up B route. The circuits required are shown on Figure 15. First it will be seen that an approach lock is provided by track circuit 125 and that this approach lock also has a time release set to free the route one minute after the lever has been replaced to the normal indication position. This time release takes the form of a thermal valve, the heating element being controlled by a " B " contact on the signal lever. After a certain time the " hot " contact of the valve makes and short-circuits the signal stick relay. This relay dropping breaks the circuit to the heating element and allows the valve to cool making the " cold " contact. With this contact made and the stick relay down the approach lock release is obtained. Other common devices used for the same purpose are time element relays operated on the vane principle ; clockwork releases, mercury dashpot releases, hand screw releases, etc.

The backlocking period comprises track circuits 126 and 127, track circuit 125 being included for approach locking. It will be noted that when track circuit 126 drops the signal stick rélay also drops, but that the backlock is not released until both tracks 127 and 126 are clear. This shunting of the approach track by the dropping of the stick relay is necessary as a general principle as otherwise if a train were to occupy the approach track before the preceeding train had cleared the backlocking tracks, it would be impossible subsequently to replace the signal lever without making use of the time release. These remarks of course only apply to semi-automatic signals.

Let us now suppose that a route is set up over the crossover from the Up B route to the Up A with 99 and 93 points reversed. Before the backlock on No. 127 lever is freed by the clearing of track circuit 127, track 128 will be occupied thus locking points 99. It will also be noted that when lever 127 is reversed stick relay 128US drops and that this in turn drops relays 138US, 151US and 148US, these relays locking points 96 and 93. The circuits are so arranged that when lever 127 is returned to normal these sectional release stick relays do not pick up until the train has passed over the respective track circuits by which they are controlled. The route is therefore always locked ahead of the train, but is free behind it.

While discussing sectional release route locking, it may be of interest to consider how the route stick relays may be used to advantage in the lever interlocking, particularly where locking is provided for traffic purposes. For example, lever 127 is released by levers 116/117 or by 125/126, as the operating department wish to prevent trains being held at the inner home signals. It is therefore necessary for these levers to be backlocked by lever 127.

It will be apparent that if this backlock were provided by a normal contact on lever 127, that as soon as this lever were replaced it would be possible in the absence of approach locking to restore whichever of the releasing levers had been previously pulled. The final route stick relay is therefore used for this purpose, thus maintaining the backlock on this lever in exactly the same manner as would be done if it were a point lever.

This same principle is maintained in connection with the platform starting signals which are released by signals on the outgoing gantry Nos. 41/42, 44, 46/47 and 48/49. It will be noted that this locking can be released by means of an automatic time release, as would be done with a normal approach lock.

The use made of back to back locking and rotation locking at Manchester Central introduced other problems into the release route locking for which special circuits were devised. For instance the set back signals 74, 75, 76, etc. lock the signals on the outgoing gantry. Now suppose a move is to be made from one of the platforms, which requires the clearing of shunt signal 46 on the gantry, and that the next move is to set back using No. 75. The train is now standing on track circuits 164, 165 and probably 166. No backlock can be provided for lever 46 as this lever must be replaced before No. 75 can be pulled. Sectional release route locking is therefore used to hold the points ahead, *i.e.* Nos. 100, 98 and 105 or 100, 96, 97, 95. Once lever 46 has been pulled with a train approaching the signal this locking remains in force until the train has either passed through the route or set back in the opposite direction.

Indication Locking.

Reference has been made earlier in this paper to the subject of correspondence between lever and operated function. The general use of colour light signals in modern installations resolves this into a question of correspondence between points and the point levers. Correspondence between the signal lever and the signal mechanism or control relay can be simply taken care of by means of indication locking. That is to say, a contact on the signal relay or mechanism is introduced into the circuit for the backlock on the signal lever, so that unless the mechanism has returned correctly to danger the lever cannot be replaced, and consequently the lever interlocking prevents any conflicting movement until the fault has been rectified. In addition indication lights repeating the signal aspect are usually placed behind the lever. Here practice varies somewhat, some Traffic

Departments requiring each aspect of the signal to be repeated, while others are content with an "off" indication only, relying on the indication lock and the extinguishing of the "off" indication to prove correspondence in the danger position.

In the case of point levers, correspondence is of particular importance, as it will be readily appreciated that there is little value in the interlocking between levers unless the points themselves are in correspondence. In earlier installations indication locks on the point lever were used for this purpose, these locks being controlled from a polarised indication relay, or in the scheme known as "dynamic indication" by current generated by the over-run of the point operating motor.

The use of indication locks made it necessary for the operator to wait for each point machine to complete its stroke before pulling the next lever, and in order to increase speed of manipulation their use has in many later installations been discarded.

If this is done the onus of proving points in their correct position is placed on the point detection relays, which in turn govern the signal operating circuits. It is therefore essential that the point operating and detection circuits should be fully protected against crosses and should be immune from false operation. The circuits and devices used to obtain this result do not come within the scope of the present paper, but their importance is here stressed as the tendency of modern interlocking is to rely to some considerable extent on their integrity.

The question of correspondence becomes particularly acute in the case of trap points. Earlier in this paper two methods were mentioned; these were:

(a) to introduce contacts on the point detection relays into the lever lock circuits, and

(b) to detect trap points in the signal circuits.

Method (a) is perhaps a little more conservative than method (b) as it ensures that the road is set to give trap protection irrespective of whether a signal is cleared or not, so that protection is retained should a movement be made without signal protection. On the other hand should a detection failure occur the lever interlocking will be tied up. Method (b), while removing this possible cause of failure from the interlocking, introduces the possibility of breaking the signal control due to momentary de-energization of the detection relay, caused possibly by the movement of a train on a parallel track.

It will now be apparent that if the interlocking usually associated with the levers should be transferred directly to the operated units, the question of correspondence then ceases to have any importance as a safety measure.

Relay Interlocking.

Let us first consider the effect of removing all lever interlocking from a modern power frame, while retaining only the electrical point detection, track circuit control and route locking. The electrical detection would prevent the clearing of a signal until the route had been properly lined up, but there would be nothing to prevent the clearing of two opposing signals at the same time.

Further one can imagine that signalmen would experience some difficulty learning to set up routes without any interlocking to guide them.

In the development of relay interlocking it therefore became necessary to design circuits which would give positive protection against opposing movements, and furnish a means of control which would permit the rapid setting of a route without the aid of interlocking. This was accomplished by abandoning the conventional type of lever frame in favour of a graphic control board.

The accompanying photograph shows the general appearance of a graphic control board. The track layout is reproduced in miniature on a panel within easy reach of the signalman. This panel carries keys to control the various signals and points, located in such a manner as to be easily associated in the mind of the operator with their respective functions. This association is geographical instead of numerical.

The panel also carries indication lights for conveying to the signalman whatever information may be considered necessary, such as track occupancy, signal and point indications. In the example shown on Plate VI the indications given are :—

1. Track occupancy (light normally out).
2. Signal indication (by a lamp illuminated when signal and control key are out of correspondence).
3. Point indication (by a correspondence light as for the signals).
4. A lock light for each pair of points indicating that they are locked either by route locking or by the clearing of a signal reading over them.

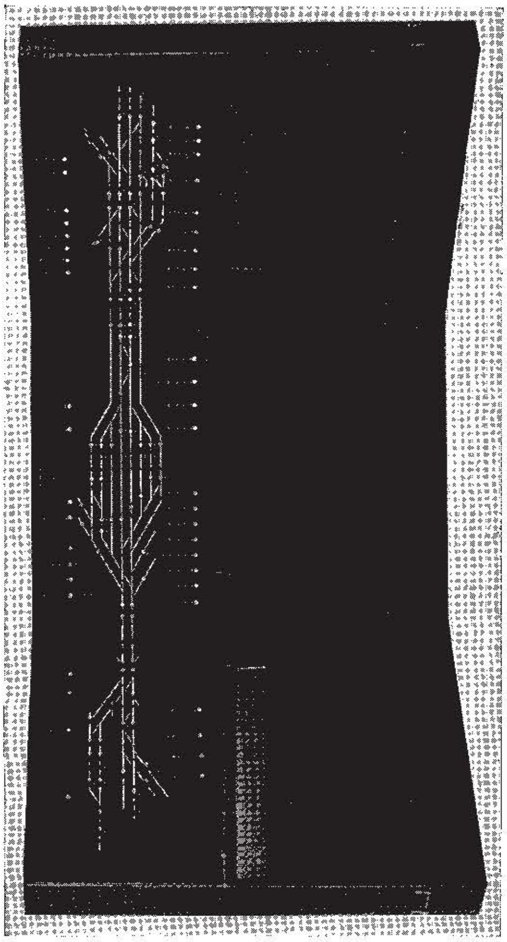

FIG. 17. CONTROL BOARD, DAYTON TERMINAL.

5. In order that the route set up may be seen at a glance the points on the diagram respond to the action of the point control keys or alternatively may be arranged to move in correspondence with the points on the ground.

The control board is normally dark in order to prevent eye strain and by relieving him of all physical effort it is claimed that one man can handle a greater number of train movements than would be possible with an ordinary power frame.

Regarding the circuits used for relay interlocking, it is not possible within the limits of this paper to touch more than the fringe of the subject, taking as an example the circuit for preventing opposing movements. This circuit will be examined only from the point of view of the interlocking principle involved, and is reproduced on Plate VI, Figure 16.

Each control key has associated with it a stick relay, GZ in the case of a signal lever, and WZ for a point lever.

Each route to be signalled is represented by two route relays (RR) connected in series, and associated with each pair of points is a lock relay (L). The interlocking between these various units is obtained as follows:

Firstly, the circuit of the lock relay includes whatever approach and route locking may be desired and is then broken through back contacts of the signal (GZ) relays. This circuit therefore provides that the clearing of a signal locks all points in the route, as the L relay in turn controls the point operating circuit.

Secondly, the pick-up circuit for a signal control (GZ) relay is through a back contact of the corresponding RR or route relay.

When relay 1GZ picks up a holding circuit is provided over its own front contact, and at the same time positive battery is applied to the route relay circuit 1RR. Now, provided that the points in the route are correctly set (proved by front contacts on the point correspondence relays, in this case 4NWCR), and also that the points are locked, proved by back contacts in the lock relays (in the example 4L), the circuit is completed to negative over a back contact of the opposing signal control relay 3GZ. Relays 1RR and 3RR therefore pick up in series, and remain so until the signal key 1 is restored. While this condition exists it will be seen that all opposing and conflicting movements will be prevented. It will be noted that for a movement in the opposite direction, using signal 3, route relays 1RR and 3RR are again energised, but this time by current flowing through their windings in the reverse direction.

Point control is accomplished by the polarised control relay WZ. As a matter of convenience a centre tapped battery is employed which feeds either positive or negative current to the WZ relay according to the position of the point key, providing always that the lock relay is energised. When the lock relay is de-energised a retaining circuit is provided over contacts on the WZ relay itself of correct polarity to maintain it in the last operated position. The purpose of the series relay LP is to prevent " preconditioning " of the route and acts in a similar manner to the ordinary signal stick relay, that is to say the lock relay L must be energised before the control key is moved to change the position of WZ.

Circuits designed on the principles outlined above were used in the installation of Relay Interlocking installed at Dayton Terminal (U.S.A.).

One operator and one director for each 8 hour shift control the whole of the layout shown in the illustration covering a distance of three miles handling, approximately 250 train movements per day. The same territory was formerly handled by 5 interlocking frames and 39 men daily.

No review of relay interlocking would be complete without some mention of the installation at Thirsk on the York—Northallerton section of the L.N.E.R. The control board is arranged on the route lever principle. Interlocking relays are employed having a mechanical lock between the two armatures. Limitation of space precludes any analysis of the circuits used, but in principle these correspond to some extent with the circuits for lever interlocking described earlier in this paper.

Conclusion.

Our esteemed President in his opening address to this Institution on the 12th of February made some remarks with reference to signalling generally which apply with equal force to the subject now under discussion.

Firstly he made a plea for simplicity, and warned us against a multiplicity of proving devices each checking the other against eventualities that may never arise, and which tend to hinder rather than assist the work of the signalman.

Secondly he suggested means for reducing the physical effort to be expended. Relay interlocking represents perhaps the ultimate limit in the reduction of physical effort. The object aimed at is to enable the man to concentrate entirely on productive effort in moving traffic to the best advantage.

Finally he considered that the solution to a number of problems would be found in a judicious blending of mechanical and electrical methods.

This paper so far has dealt only with electric interlocking as applied to power signalling. The methods which have been described are equally valuable when used in conjunction with new or existing mechanical apparatus. For example, when it is required to work outlying points by power or to close a signal-box and work the connections from an adjacent cabin this can readily be done by using a control panel electrically interlocked with an existing mechanical frame.

Again should it be desired to obtain the benefit of colour light signalling while retaining the simplicity of mechanical point working the interlocking between the mechanical levers and the slides or miniature levers controlling the signals can most conveniently be made electrically.

In conclusion, the Author hopes that these notes will assist in proving that electrical methods are not fundamentally complicated, and are even in some cases simpler than their mechanical equivalent, besides bringing other advantages in the way of greater flexibility.

DISCUSSION.

The President said he was sure they had all listened to Mr. Webb's paper with very great interest. That gentleman had gone to great pains in the preparation of its details, far more than could be appreciated whilst listening to him, and he hoped they would show their interest by placing any questions they might have before Mr. Webb.

At the Council Meeting that afternoon the discussion of papers came under review and the opinion was expressed that the membership generally should be more in evidence in discussions.

He was personally much interested in the growth of the definition of interlocking, as explained by Mr. Webb. Originally with the mechanically operated and interlocked lever frames, interlocking was understood to be the actual controls between the levers comprising the frame. Facing point locks, detectors, and slotting of signals, etc., did not then come under the actual definition of interlocking, but the features brought out in the paper struck him as being sound.

Mr. Webb mentioned that a general principle from the traffic point of view was " the releasing of a route as early as possible." This was very necessary and obtainable with track circuiting, but the President suggested it was also very important to lock a route as late as possible. Also that when once a route was set up it should be capable of rapid release in case of emergency. This was demonstrated not long ago at Victoria Station, Manchester, adjacent to where they were sitting.

Mr. Robinson and the Inspecting Officer of the Ministry of Transport commended a signalman at that station for his prompt action in altering the route set for an approaching train and so avoiding what might have been a very serious mishap.

The means of " insuring the integrity of the route " could be debated at length and one had to be content with a choice of evils.

The Author stated that generally, with mechanical interlocking, the signal levers when reversed alone held the route and beyond this the responsibility rested with the signalman to protect the train against derailment.

Many cases had occurred when the integrity of the signalman had been utilised to advantage to sidetrack an approaching train, by his being able to disturb the route set up when, say, that route had been fouled later.

Enquiries into irregularities had shown that the integrity of the signalman was not always reliable. The choice of evil therefore was :—

(*a*) Whether a signalman should be prevented from disturbing the route when a train was approaching, to prevent derailment ;

or

(*b*) Whether to rely upon the integrity of the signalman to disturb the route when a train was approaching to prevent accident due to the route being subsequently fouled.

The President was going to ask the Secretary to make a note that when an open date occurred a free discussion on ways and means of " insuring the integrity of the route " would be very illuminating and interesting.

Finally, he really admired Mr. Webb's adroitness in applying the remarks he made in his Presidential Address to a subject he had not intended to deal with.

The President congratulated Mr. Webb on his paper, the first of its kind read before the Institution and which he was sure would lead to an animated discussion, for which purpose it was now open.

Mr. E. G. Brentnall wished to congratulate Mr. Webb on his excellent paper. No doubt electrical interlocking would become much more important in future, and such papers were valuable as they enabled the whole subject to be discussed. In Plate I., Fig. 3, 1 was released by 2. Why was the E lock provided on 1 lever as well as the A lock ? What was the necessity for the A lock on 2 lever ? The thermal time release circuit shewn in Plate V., Fig. 15, was interesting. In such circuits the provision of both heating and cooling contacts were necessary to give a constant time period for the release. With regard to the route system circuits shown in Plate VI., Fig. 16 ; if an outer home signal, say No. 5, were provided in rear of No. 3, would the circuits for Nos. 3 and 5 signals be combined, or would a separate route circuit be provided for No. 5 signal ?

A route relay interlocking had been in use at Thirsk on the N.E. Area, L.N.E.R., since early in 1933 and had proved entirely satisfactory. The route system made for very quick operation : as an example, 14 sets of points and the signal leading over them were operated, by turning one switch, in three seconds. The panel was only 12 feet in length and was operated by one man. Two were originally employed, but they were in each other's way ; if a conventional power frame had been provided, approximately 170 levers would have been necessary, with a frame length of 35 feet.

The circuits for a route system were much simpler than for an individual operation system, as no conditional interlocking was required.

Mr. P. A. Langley said it was interesting to note the facilities which electrical interlocking afforded. For example : half-rotation or sequential locking between signals, was automatically obtained by omitting the converse of the normal lock. Also, as the Author said, backlocking facilities were obtained by sectional release route locking, not given in mechanical locking.

Referring to the tabulation of interlocking ; as the circuits are prepared from this it was very important that the terms used should be perfectly clear. He would like to see the word " backlock " substituted by " reverse lock." Apparently where only one lock was used for both lever locking and other controls, the term " backlock " could be interpreted to mean either reverse or normal indication for a signal lever, as in Figs. 7 and 8 : 6 backlocked by 9. Would it not be better to say that all signals should be backlocked and all points reverse locked ?

Obviously it was necessary to be more precise in tabulating electrical locking than it was with mechanical locking. For example, all during-stroke locking had to be tabulated. Here again he would prefer to see it in the following form. Take for example lever number 74 locking 87 and 88 normal and reverse. The during-stroke locking for these would read : 74 released by 87N or R and 88N or R. Also in tabulating the locking 3 locks 1 when 2N it was necessary to insert it in the release column ; that was to say : 2 released, or was reverse-locked, by 1 when 3 was reversed. This, of course, was not generally done when tabulating mechanical locking.

Referring to Fig. 6, very often they found that 2 was released by 3, and then, with mechanical locking, 1 locking 2 normal and reverse was superfluous. However, with electrical locking it would appear to be simpler to provide the bothway lock in preference to the arrangement shown in Fig. 5. The tabulation should, therefore, be made accordingly.

Referring to the lock circuit for signal number 74 (Fig. 12), it was noticed that 89 locked 74 during-stroke, but this was not shown in the tabulation.

It was assumed that normal and reverse rear locking of points by signals was not necessary, as the latter were locked by respective track circuits. During-stroke locking, however, was necessary for cases of conditional locking such as 74 backlocked by 125. 126 W 89N. Also, was it correct to say that as during-stroke locking by 87 and 88 was automatically given by the conditional locking, the tabulation need not show it, any more than it did not show the during-stroke locking by 89 ?

With regard to indication locking, to control the signal lever normal lock by the trap points detection relay appeared to Mr. Langley to remove both the objection referred to in methods (*a*) and (*b*) on page 85.

Provision of two lever locks, one for lever interlocking and one for other controls, seemed desirable for the following reasons :—

(i)—The lever interlocking could be isolated and all locks sealed.

(ii)—No confusion between backlocking and reverse locking would arise.

(iii)—Separate indication to the signalman would be possible and he would then know if he were tied up by lever locking or other controls.

Finally, the Speaker asked the Author if he could say what were the main factors which decided whether an installation should be of miniature lever type or the relay interlocked panel type.

Mr. S. W. Spendlove wished first to express to the President and Council the thanks and appreciation of his many colleagues and himself for holding that meeting in Manchester. The majority of them who were stationed at various points in the North found it extremely difficult to attend meetings in London, and although they received the Proceedings, they missed the opportunity and privilege of associating with other members, and of listening to, and possibly joining in, the discussions. He was pleased to say that the holding of the meeting there last year resulted in new members being enrolled, and hoped similar results would follow that day.

The subject of the paper they had heard read was one of particular and live interest at the present time, and he congratulated the Author upon the selection of one which should create an interesting and helpful discussion.

The paper dealt principally with electric locking as applied to power signalling and the Author had pointed out the developments taking place in the direction of dispensing with mechanical locking and depending entirely on electric interlocking in power frames. This was, of course, an accomplished fact in a number of new power signalling installations, but the phase of the subject which, Mr. Spendlove thought, was of particular interest was the extension of that principle to new or existing mechanical frames, referred to at the end of the paper. Before dealing with the diagrams in it, therefore, he would like to refer to the principle itself, *viz.*, mechanical *versus* electric interlocking on mechanical frames.

The introduction of track circuits, block control of signals, approach and other locking, had resulted in large numbers of electric locks being installed for those purposes, and as such locks could also be employed for interlocking mechanical levers, did it not seem the correct policy to do this wherever possible, and so save the expense of alterations to mechanical interlocking? In numerous signal-boxes there were already so many electric locks provided for the controls mentioned, that the addition of very few electric locks would be necessary completely to interlock the frame electrically.

They already depended entirely upon electric locking for safeguarding and controlling traffic movements of primary importance, so that it seemed that no arguments could be raised against its safety or reliability. The amount of lever interlocking that could be done electrically was practically unlimited, and the preparatory work that could be done in wiring up such circuits without interference to the signalman's work made the actual alterations very much simpler and quicker than with mechanical locking.

Mr. Spendlove would be obliged if the Author would be good enough to explain a few points in the diagrams :—

Plate I., Fig. 3. What was the necessity for a reverse lock on lever 1 and a normal lock on lever 2 in the electric interlocking? There were none in these positions in the equivalent mechanical locking.

Fig. 4. What was the object of the reverse electric lock on lever 1?

Fig. 5. Why was a reverse lock shown for lever 1, a normal lock on lever 2, and a reverse lock on lever 3?

Page 79, paragraph 2. Reference was made to Fig. 9. In the locking table, lever 13 locked 12 in the normal position, and 6 locked 12 in the reverse position. In Fig. 9, however, both 6 and 13 appeared to lock 12 normal and reverse. In Fig. 10, 13 locked 12 normal and 6 locked 12 reverse, in accordance with the locking table. Should not Fig. 9 be drawn as shown in Fig. 10?

Page 79. Locking table for levers 59 and 60. Mr. Spendlove could not reconcile the locking given there with that shown in Fig. 11, where 59 appeared to be locked normal and reverse by everything. As a catch handle contact was shown as in use, why should not NA and RE contacts be employed instead of A and E?

Pages 82 and 83. Paragraphs 5 and 1 respectively. This referred to an approach lock with time release in connection with route locking, and the circuits were shown in Fig. 15. Did it not appear from this diagram that if the approach track were not shunted by the back contact of the stick relay, the indication lock could be obtained without waiting for the time relay to operate when replacing the lever with tracks ahead clear, as the " cold " contact on the thermal relay was normally made ?

It would appear that, under the conditions of track occupancy given on page 83, paragraph 1, the backlock of lever 127 would be released immediately the backlock tracks had been cleared, because the " cold " contact of the thermal valve was not broken until the valve heated up after lever 127 had been placed in the B position.

It was noticed that, although electric locks were provided on all point and signal levers, lever contacts had been used to control other levers. No proving contacts were shown, and the Speaker would be glad to know if the Author considered it unnecessary to utilise proving contacts, for proving the levers actually locked.

Mr. T. Palmer said that in the old " B " cabin at Manchester Central there was a 115 lever frame, 16 locking cases and 1,100 tappets.

At a recent meeting in London someone argued that you could prove interlocking by seeing the lock driven from one end of the bar into the slot at the other end. Mr. Palmer thought you would have some difficulty in doing it in that cabin. That lever frame gave over forty years service, and if the present one gave the same service it would be a credit to every one concerned. At the same meeting someone argued that it was much more difficult to make an alteration to an electrical than to a mechanical installation. His experience was that it was very much easier to alter an electrical than a mechanical. You had to be very careful in preparation, but the actual alteration was very much easier indeed.

Mr. Palmer was glad to see what Mr. Webb said about proving traps. He thought that traps should be proved in that way, but should not that also apply where you made one lever precede another for trapping purposes ? Take a place like Manchester Central, where many of the points, if not pulled for traffic purposes were really acting as traps. As to the question of checklocking, where it was installed you had proof that the point was in correspondence with the lever ; the trouble was slowness of operation in having to wait for the indication before the next lever could be moved. Of the two methods of proving correspondence between levers and points referred to on page 85, by arrangement (A) the working was slower as it was necessary to wait for completion of operation before lock free was obtained for the next lever. By method (B) the point lever operations could be completed without waiting for the indication, the final operation of the signal proving that the levers and points corresponded.

So far, the whole of the installation at Manchester was working very satisfactorily indeed and giving very little trouble.

Mr. E. W. Challis would like to join the previous speakers in thanking the Author of the paper. It had been of great interest to him, as it was about a subject with which he had been particularly associated.

On pages 79 and 80 there were translations of an interlocking table. One railway in this country, that had had considerable experience of electrical locking, endeavoured to translate the locking into a table of straight releases, treating every lever as locked until it is freed, before designing the interlocking circuits. Now the subject had developed, Mr. Challis thought the time had come when such a table should be standardised, and that Mr. Webb had made a very good effort indeed to arrive at the best solution. The Author had hit the nail on the head, when he stated very clearly the necessity for all reciprocal locking to appear as such on the interlocking table. With regard to alterations to electric interlocking circuits, to which certain speakers had made reference, the Speaker had been actively associated with electrical interlocking installations both at home and abroad, and had seen extensive alterations made. His experience was that making them was a matter of simplicity and care ; what must be impressed on the wiremen and inspectors was the necessity for a most careful check and test afterwards. Mechanical locking alterations were comparatively easy to test out, and electrical locking was just as easy, up to a point. On the other hand it was very difficult to be able to prove, in the latter case, that nothing had been disturbed that should not have been, and Mr. Challis advocated that in any case of alteration, every interlocking circuit having the faintest relation to it, should be tested with great care, in addition to the actual locking alteration itself.

Mr. J. H. Currey thanked Mr. Webb for his paper. It gave him an opportunity of raising a point that had been in his mind ever since he had had any experience with electrical interlocking, and that was the extreme ingenuity shown by the circuit designers. Probably for the sake of economy they might start off through one contact on a relay and, after many wanderings through other contacts, finish up with as many as thirty, forty or even fifty locks. Think of the poor lineman who was called out to a fault and had to follow through one of those diagrams in a hurry. If the circuits were simpler and not more than, say, five locks were taken off any one contact, it would enable the lineman to save time when faults occurred.

Mr. C. Carslake said that the discussion had been exceedingly interesting and, in view of the President's comments about the younger members taking the principal part in the discussion, there was not much left for him to say. One of the principal things which occurred to him during the discussion was the question of the simplicity of electric as against mechanical interlocking. For many years he was definitely against dispensing with mechanical interlocking in connection with power signalling, but in the King's Cross installation where mechanical interlocking was in force, a complicated alteration had to be taken in hand some weeks after the installation came into operation. This locking alteration took five consecutive Sundays to carry out, with all the consequent checking after each stage had been done, before ordinary traffic could be resumed. With electric interlocking this same locking alteration could probably have been done in one Sunday in about five hours, and from that time onwards, and also after his experience with Fenchurch Street, Mr. Carslake had been a very strong advocate of electric interlocking.

The last speaker had made a very strong point on the question of simplicity of circuits and he certainly considered that simplified circuits, not only for the sake of the maintenance linemen but also in working and installation, were most important. With one operating contact carrying a number of important branch circuits much was liable to go out of order when it was defective, and if circuit designers on the contractors side could be a little more generous with their contacts and not so ingenious with their circuits the railway signal engineers would owe them a debt of gratitude.

The President invited Mr. Webb to reply to the discussion, saying he thought it would take him as long to do so as to prepare the paper.

Mr. W. H. R. Webb said he would just deal briefly with one or two points; the matter of circuits he would rather deal with after studying the shorthand notes. As regards the President's remarks, he agreed with him that releasing the route as early as possible was vitally important, but was not sure he did so as regards locking it as late as possible. He might put it in this way: release as early as safety will allow and lock as early as is convenient.

As regards the protection from fouling moves, he thought they had to make a compromise between approach locking and giving the signalman an opportunity of moving the points under the train; in his opinion it was more important to protect the human element than the apparatus itself. He had not had the opportunity to analyse accident statistics in detail, but believed that if this were done it would appear that possibly ninety-five per cent. of accidents were caused by failure of the human element, and not more than five per cent. by failure of the mechanical element. Therefore we should do everything possible to safeguard the actions of the signalman, rather than guard against unusual happenings or apparatus failure. As regards the importance of backlocking and its desirability, Mr. Webb thought it should be as complete as possible.

Mr. Brentnall asked what was the necessity for the A and E contacts in Fig. 3. As a matter of fact these contacts were not really essential to give the equivalent of the mechanical locking shown in the diagram, but if they were omitted then the electric lock on lever No. 1 would have to be cut in the N position only and electric lock on lever No. 2 in the R position only. This answered one of Mr. Spendlove's queries concerning the reason for cutting the lock on lever No. 1 in the R position although no such locking existed in the mechanical locking. In practice in all-electric interlocking it was always usual to cut the lock in both positions so that each lever lock was standard; the actual locking required was obtained entirely by means of the circuit arrangement. Mr. Brentnall also raised a query regarding the relay interlocking circuits. The circuits illustrated in the paper had been drawn simply to illustrate the principles involved. Naturally some additional locking would be required in the case of a more complicated layout, but for the sake of simplicity it was usually advisable to use one pair of route relays for every opposing move. Mr. Langley spoke of the tabulation of lever interlocking, and this was afterwards stressed by Mr. Challis. The best way to show electrical interlocking to-day, as Mr. Challis suggested, was to use a table of releases, every lever being normally locked until it was freed. The table as translated by the circuit man could well be used in the first place, and no doubt that would take place as soon as more people got used to designing electrical interlocking. In many cases electrical locking tables were prepared by a man with previous experience of mechanical locking, who, of course, prepared them in the way familiar to him. It was then necessary for the circuit designer to translate this into the form mentioned by Mr. Challis.

Mr. Langley also raised the question of one lock *versus* two and of sealing the lever interlocking. One lock or two was a matter of individual preference and depended on the mechanism of the frame. Electric track locking was equally important as lever interlocking, and if the lever interlocking was to be sealed so should any track locking.

Mr. Webb was very glad to have Mr. Spendlove's further argument in favour of electric interlocking. One of his queries concerning the circuits he had dealt with in reply to Mr. Brentnall; the remainder he hoped to amplify in a written reply.

Mr. Palmer was thanked for the very interesting information he had given concerning the old Manchester cabins. On the question of the interlocking of traps, Mr. Webb agreed with him entirely on the matter of principle, but from the practical point of view it was necessary to make a compromise to avoid undue complication.

Mr. Currey spoke of simplifying interlocking circuits and suggested it would be simpler if separate contacts were used for each particular one. That would of course multiply the total number of contacts required and Mr. Webb suggested that the circuits were not in fact simpler when a vast number of contacts were used, because there was then a greater number of possible points of failure. Mr. Currey suggested that the failure of one contact might affect 40 or 50 locks. While this was quite true theoretically he believed that, provided a lineman knew his job thoroughly, as of course he should, he would know at once that that combination of 40 locks meant a failure of that one contact and he would be able to go right to the point. Finally he would like to thank Mr. Carslake for his very interesting remarks on the comparative ease of making an alteration to electric interlocking as compared with mechanical interlocking.

In a further written reply **Mr. Webb** said he found there were one or two points not covered in his spoken remarks. Mr. Spendlove enquired the necessity for certain locks in Figs. 4 and 5. The same remarks applied as in the case of Fig. 3; although these locks were not really necessary to give the equivalent of mechanical locking they would be supplied for the sake of standardisation.

Regarding Figs. 9 and 10 and the locking in Fig. 11, the reasons for it were explained somewhat briefly in the second paragraph on page 79 of the paper. The condition was as follows :–

Lever No. 6 locked 12 in the reverse position because until 12 had been pulled lever 6 would remain locked. This arose from a condition not shown in the figure, which was 6 released by 12, operated on a separate circuit. The same fact had to be borne in mind when comparing the locking shown on the tables on pages 79 & 80 with the circuits in Figs. 11 and 16. Regarding the necessity for A and E contacts, as catch handles are employed, Mr. Webb would say that these were most necessary and that NA and RE contacts could not be used in their stead. If this were done it might be possible with two levers which locked each other, for a condition to arise enabling both levers to be obtained at once; both locks would be energised if the levers were pulled simultaneously.

With reference to Fig. 15, he agreed that the lever could be replaced without waiting for the time release, except when the approach track was occupied. It should be remembered that for the signal to be clear the stick relay must be up, so that although the cold contact of the thermal relay was normally made the back contact of the stick relay was normally broken.

With reference to page 83, paragraph 1, on the same subject, it was intended that the back lock should be free under the conditions stated, in view of the fact that the time release only functioned in connection with the approach locking and not in connection with the back locking track circuits. Proving contacts on electric locks were not considered necessary, at any rate in the case of power frames in which the lock had a definite mechanical throw down, as was usual in most designs. The introduction of proving contacts would undoubtedly complicate the installation unduly, without giving any equivalent benefit in additional safety.

The President expressed thanks to Messrs. Dolman and Box, Jnr., for providing the lantern and screen and for operating the lantern.

It was, he said, exceedingly gratifying to find such a large attendance at a meeting in the provinces; if it was not a record meeting it was very nearly so. The Council were most anxious to continue the provincial meetings. He was pleased to find among them a number of interested visitors. There might be some there on a kind of trial trip to see whether the Institution was worth joining. There were about fifteen present from Metropolitan-Vickers, who were connected actively with the manufacture of signal appliances. They had Mr. Brookes, the engineer in charge of the Signal Department there, and Mr. Simes, who was superintendent of a department also dealing with signalling at Metropolitan-Vickers. He suggested they should put in application forms and encourage those they controlled to do likewise.

Mr. Webb must have been much gratified to have such interest taken in his paper. It was the kind they wanted more frequently at their meetings, and was particularly interesting, as that afternoon they had had an opportunity of seeing an actual installation. If there were any more queries, those of them who attended the Summer Meeting would have a further opportunity of stating them. He did not think Mr. Webb really wanted a vote of thanks because he had already had that in their attention and their reception of the paper, but they would be lacking if they did not say: "Thank you very much!"

The paper came to be prepared because when he was elected President he saw that they were going to be short of papers during his year of office. Subsequently he met Mr. Webb on Euston Station and said to him: "You are the very man I am looking for. I want a paper from you," and this one was the result. He said to them all "go you and do likewise." If they would it would give a great impetus to the Institution and certainly be the means of helping to get better discussions and more papers than they had had in the past. He asked them to show their appreciation of Mr. Webb's efforts with acclamation. Members did so and Mr. Webb expressed his acknowledgments.

The President announced that the next meeting would be held in London on May 20th, at the Institution of Electrical Engineers, when a paper entitled "Electro-Pneumatic Signalling" would be read by Mr. R. S. Proud.