Technical Meeting of the Institution

held at

The Institution of Electrical Engineers

Thursday, December 14th, 1967

The President (Mr. H. W. HADAWAY) in the Chair.

The Minutes of the Technical Meeting held on November 15th, 1967, were read and approved.

The President then welcomed Dr. Ing. K. W. Oehler (Member) and requested him to read his paper entitled " Continental Practice and Policy on Fail Safe."

Continental Practice and Policy on Fail Safe

*by Dr. Ing K. W. Oehler (Member)**

1. INTRODUCTION

In comparing Continental signalling practice with British in this paper I have taken the term " Continental " to refer to the methods used in Germany, the Scandinavian countries, Austria and Switzerland. Although in these countries the methods are not identical, they show great similarity. For this reason, I shall refer hereafter only to the methods used in Switzerland. The methods used in France, Spain and, after World War II, in Holland are more or less similar to those used in Great Britain and the U.S.A.

Comparing a station of which all points are hand operated with another station where all point and signal levers are concentrated in a lever frame, we find an increase of the work to be done by the signalman responsible for the train movements. The work previously done by several local guards has now to be carried out by one man. The interlocking relieves him only partly of his responsibilities. Power interlockings reduce the strenuous labour, but only the most modern electrical installations relieve the operating staff of their work to the extent that crossing stations on single lines may be left unattended, or that in other stations routes are selected by the train itself, e.g. by means of the train description. In such cases this control equipment has taken over not only the whole work but also the full responsibility of the operator, whose duty is reduced to supervising. Therefore, from an interlocking, which has taken over both the work and the responsibility, we expect something more than reliability—we expect safety.

**Integra Limited*

2. DEFINITIONS

We may distinguish two kinds of safety incorporated in an interlocking; "external" safety and "internal" safety.

External safety deals with the safeguarding of train movements against the dangers inherent in railway operation. Five such dangers are well known:

(1) Dangers caused by the points as movable parts of permanent way.
(2) Side-on collisions caused by the wrong position of points in adjoining tracks.
(3) Movements towards an occupied track.
(4) Running into a preceding train or movement.
(5) Head-on collisions.

"Internal" safety is concerned with the way in which interlocking accomplishes its task, i.e. the quality of its work. Here the highest degree of reliability, or in other words safety, is required.

The term "safety" needs a more exact definition in connection with the expressions "reliability" and "probability" respectively. Each designer wishes to make his designs as reliable as possible. He expresses the measure of reliability as a reciprocal value: the "probability of failure." This is the number of failures to be expected in relation to the number of operations which have to be executed by a certain element of a construction. E.g. when 100 relays are tested under working conditions and after 10^7 operations no changes can be established either in the mechanical parts or in the contacts, the probability of failure is less than 10^{-7}. But such tests do not take care of all the external influences to which these components are exposed in their practical application. These influences are mostly connected with a time factor, examples being vibrations, corrosive chemical atmosphere or voltage peaks produced by sparking at contacts, etc.

Manufacturing defects (poor workmanship) which show only in the course of time can be eliminated if all components work for a certain time under full load. This method is often applied to electronic components. It results however only in a reduction of the probability of failure; this probability will never become zero.

In spite of these uncertainties some people estimate the reliability of whole systems by considering the reliability of the components. But often they forget that the reliability of electrical connections has also to be considered. The many soldering points, plug-in devices, connecting wires etc. also produce possibilities of failures which have to be taken into account. Therefore, in evaluating whole systems, the designer can only rely on his experience and perhaps on his imagination.

He will try to increase the reliability of his components by increasing their dimensions, thus utilizing them only for a part of their normal load. But this only increases the reliability of the different components, not the safety of a whole system. Since the failure probability will never reach the value 0, "safety" will not be obtained by this approach.

Calculations of probability have not much meaning for another reason. Probability tells us only that in the average one failure may be expected for a certain number of operations, but probability never says at what time this failure will appear. It may be tomorrow, or even to-day, possibly with catastrophic consequences. Therefore we have to apply other methods. One such method could be very careful maintenance at short intervals, with minute checking of all parts, but would entail great expense.

3. A CONTINENTAL APPROACH TO SAFETY

But there is another possible method of increasing reliability, a method which is followed in the Central European countries mentioned earlier. It is well known that the external safety mentioned above is accomplished by the interlocking as it prohibits or permits train movements. Now if it is possible to ensure that failures in the interlocking can only result in a prohibition and never in a permission, internal safety could be achieved in spite of the fact that the possibility of failures is accepted. But we have to pay attention to still another requirement. It is necessary that each failure compels the attention of the man in charge by withholding a permission which could otherwise be given. Only in this way can it be ensured that the failure will be remedied within a short time. Otherwise the failure, being unnoticed, could combine with another one, taking place later on and so result in an unsafe condition i.e. something would be permitted which should not be. A concession to probability can be made by supposing that no other failure will occur during the time a permission has to be given under the personal responsibility of the signalman, e.g. by operating a sealed release. However this probability is less by many powers of 10 than the occurrence of a single failure so that in spite of this limitation we can use the word " safety." Considering the problem of safety this way, we can say that we have to deal only with the failure probability of one single component and not with the failure probability of the whole installation (which is a combination of the failure probabilities of the various components).

Unfortunately there is no universal rule for this method of obtaining safety, but we can establish some principles, of which the most important ones are enumerated below :

(1) The correct completion of an action which has been initiated must be confirmed by an active indication.

(2) Every indication which might result in a permission must take the form of an action, e.g. the current energizing a relay during the time the permission is effective, or a pulse changing the position of a latched relay.

(3) Different independent actions may take place at the same time if the indications of their correct completion are switched in series.

(4) Dependent actions have to be switched in cascade via the indication i.e the initiation of an action is identical with the indication of the previous action.

(5) Continuous indications must be interrupted during each working cycle. This proves that the indicating device is capable of work, i.e. the information is a result of an action.

(6) The final permission for a signal to be cleared must be obtained by the indication resulting from two independent actions.

3.1. An Operating Example

The easiest way to demonstrate these principles is to explain them by an example, for which point operation and control circuits may be useful.

The circuits are shown in fig. 1, and the various actions are listed in their order in Table 1. The key explains the meaning of the various relay designations and the use of contact symbols in the circuits. Coils are represented by circles. When a relay has more than one coil the circles are numbered accordingly. It should be noted that in fig. 1 part of the circuits is shown twice. This is done to indicate that the control circuitry is the same for point machines with either three-phase or single-phase motors.

The circuit steps will now be briefly explained :

(1) By operation of a common button the appropriate general command push-button relay (GCPb) is energized and closes its contact. In the same circuit there is a contact of the point push-button relay (PbR), located in the point control unit. Current flows via contacts of track relay TR, trailing indication relay TrKR and the locking relays WL, UL and TpL via another contact of PbR through the third coil of the start relay (left) RL. As the points were moved to the right by the previous operation, the position relay for the right position, RZR 1, is still latched and holds its contact closed in this circuit.

(2) Start relay RL is energized and with its back contact it cuts off the selection contacts in the circuits of the 3rd coil of start relay (right) RR and time relay JR. A front contact of RL energizes general start relay Rst 1 as well as the condenser of time relay JR.

(3) General start relay Rst 1, forms, with restore relay Rst 2, a pair of latched relays. Therefore by the picking-up of Rst 1, Rst 2 is released and ready to indicate the completion of the point machine operation. A back contact of Rst 1 interrupts the circuit of point detection relay WKR, causing its release.

(4) With Rst 1 picked-up and Rst 2 released the trailing indication relay TrKR is energized. The actual trailing indication is however suppressed by a contact of Rst 1[1].

(5) Via contacts of the energized TrKR, the de-energized Rst 2, the still energized RL and the de-energized

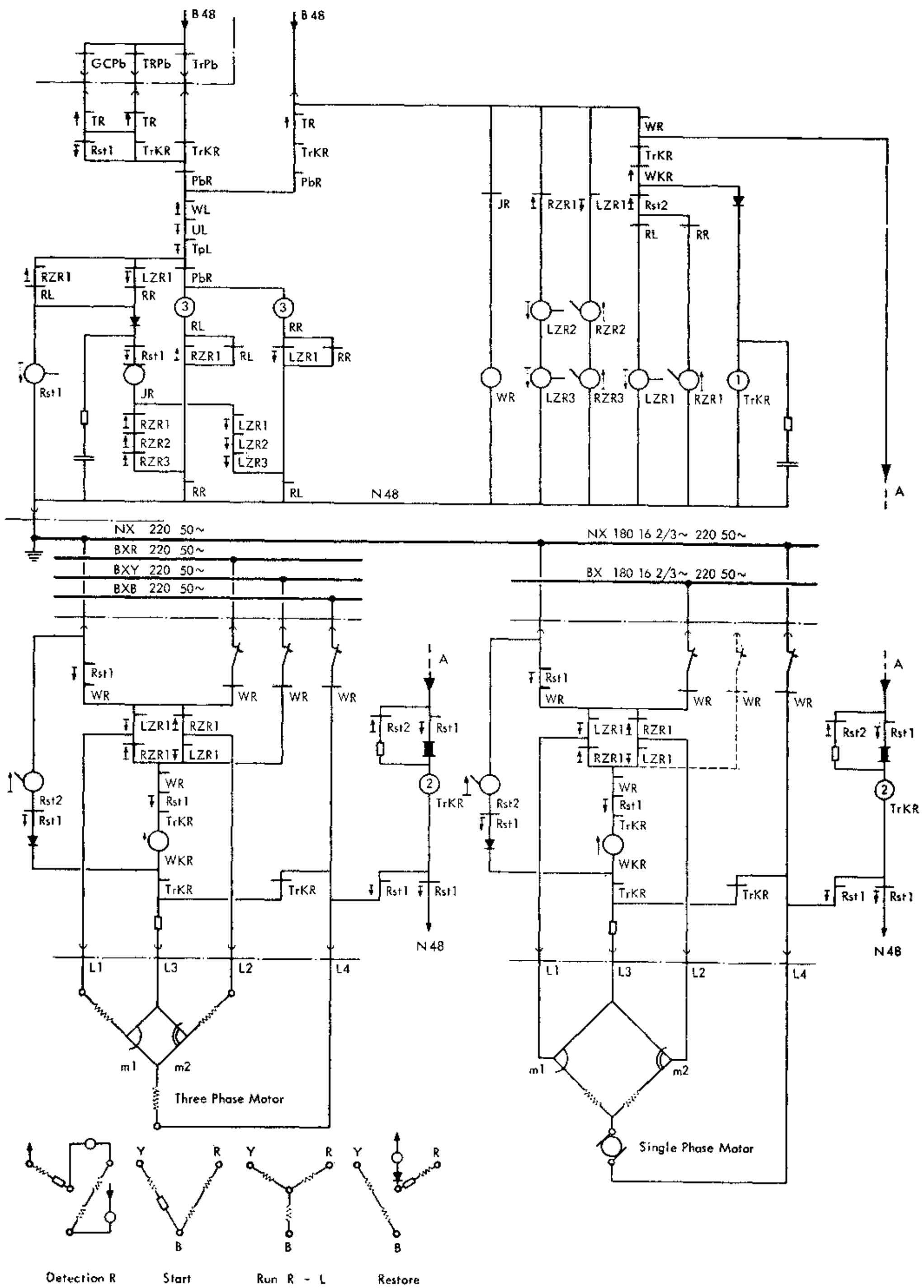


Fig. 1. Circuits for point operation and control.

Table I

	Operation commanded by	Operation started under the condition that	Relay to be checked	Result
1	↑ GCPb + ↑ PbR	↥ WL ↧ UL ↧ TpL		↑ RL
		↑ TR ↓ RR ↑ RZR1		
2	↑ RL	↓ TrKR		↑ Rst1 (JR)
3	↑ Rst1			↧ Rst2 ↓ WKR
4	↧ Rst2	↥ Rst1		② ↑ TrKR
5	↑ TrKR	↓ WR	↓ WKR	↑ (TrKR)
		↧ Rst2 ↑ RL		↑ LZR1
6	↑ LZR1 (↓ GCPb + ↑ PbR) *			↧ RZR1 preparation L1 → Y L2 → R
7	↧ RZR1			↥ LZR2 ↧ RZR2
				↥ LZR3 ↧ RZR3
		↥ Rst1	↧ RZR2 ↧ RZR3	↑ JR 6sec
8	↑ JR			↑ WR
9	↑ WR			↓ TrKR after .5sec
				Y → L1 R → L2 B → L3 + L4
10	Start Right–left			m1
11	m1			Y R (↓ TrKR) B Run
12	m2 Stop		↓ TrKR	↥ Rst2 ↧ Rst1
13	↧ Rst1			↓ JR
14	↓ JR			↓ WR
15	↓ WR	↓ TrKR ↧ Rst1		↑ WKR

* After item 5 the pushbuttons for the command of the operation may be released: ↓ RL.
Next command reverses the movement.

power relay WR the operation relay of the left position LZR 1 is energized. In this circuit the point detection relay WKR is proved down. Coil 1 of relay TrKR together with the condenser are switched on (timing for step 9).

(6) The point position relays for the left and right positions, LZR 1 and RZR 1 repectively, form also a pair of latched relays. So LZR 1 picking-up releases RZR 1 which in its turn latches LZR 1. As general start relay Rst 1 is also latched, both push-buttons may now be released.

Owing to the release of the push-buttons start relay (left) RL is released and the circuit is prepared for the reversal. The change of the position relays LZR 1/RZR 1 results in a change of the phase connections of L1 and L2, which corresponds with

KEY TO FIG. 1 AND TABLE 1 (Opposite)

GCPb	General Command Pb Relay	RR	Start Relay Right
TRPb	Track Relay Elude Pb Relay	RL	Start Relay Left
TrPb	Trailing Restore Pb Relay	RZR 1	Right Position Relay 1 } *
WL	Individual Point Locking	LZR 1	Left " " 1 } *
UL	Route Locking	RZR 2	Right " " 2 } *
TpL	Trap Locking	LZR 2	Left " " 2 } *
TR	Track Relay	RZR 3	Right " " 3 } *
PbR	Point Push-button Relay	LZR 3	Left " " 3 } *
Rst 1	General Start Relay } *	WR	Power Relay
Rst 2	Restore Relay } *	JR	Time Relay
WKR	Point Detection Relay	m 1	Motor Contact 1 } **
TrKR	Trailing Indication Relay	m 2	Motor Contact 2 } **
		L_{1-4}	Cable conductors

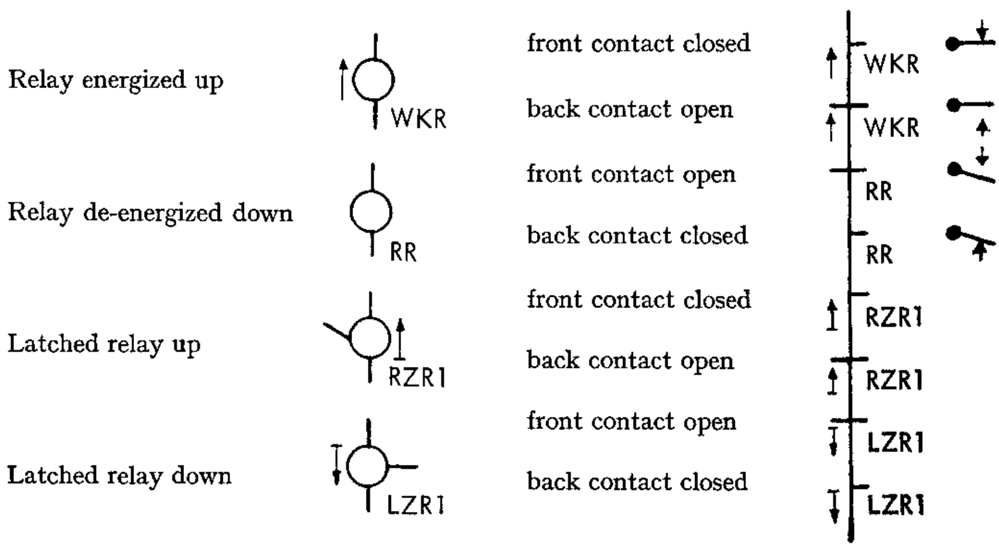
* Latched Relays

** m 1 changes at the beginning of movement R → L or at the end of movement L → R

m 2 changes at the end of movement R → L or at the beginning of movement L → R

In three-phase point motors contacts change with temporarily both sides closed

In single-phase motors contacts change with temporarily both sides open



the running of the point machine from the right-hand to the left-hand position of the tongues.

(7) A contact of relay RZR 1 now energizes the repeat relays LZR 2 and LZR 3. They release RZR 2 and RZR 3 and are themselves now mechanically latched.

The contacts of the released relays RZR 1, 2 and 3 together with a contact of latched relay Rst 1 connect time relay JR to the condenser. The repeat relays RZR 2 and 3 have to be proved down as they are released at the same time and independently.

(8) The time relay JR energizes the power relay WR for 6 seconds.

(9) The energized WR connects the three-phase supply to the motor whilst another contact disconnects both coils of TrKR. This relay remains still up for about 0.5 seconds owing to the condenser across coil No. 1. During this time contacts of TrKR connect phase B, already on wire L 4, also with wire L 3, which results in the start of the motor in V-connection.

(10) As soon as the motor starts to run motor contact m 1 changes.

(11) The change of contact m 1 results in the disconnection of line L 3 and the running of the motor in star-connection.

During the run, the throw rod, the locking mechanism, the tongues, the detection rods and the detection lock are operated in succession. As this is a complete cycle, motor contact m 2 is only able to change fully if the closed tongue is actually locked in the end position.

(12) Via a contact TrKR, which has released in the meantime, restore relay Rst 2 is connected between phase R and neutral by means of motor contact m 2. A half-way rectifier is sufficient to make the relay pick-up and so the latched general start relay Rst 1 is released, interrupted at the same time the circuit of Rst 2. The de-energized position of relay TrKR is proved in this circuit.

(13) Relay Rst 1, returned to normal position, also cuts off the condenser from time relay JR so that the latter releases.

(14) Consequently JR causes the release of the power relay WR, which disconnects the three-phase supply.

(15) With a contact of WR the detection relay WKR is energized again via contacts of TrKR and Rst 1.

From the above it can be seen that each completion of an action is indicated by contacts of a relay, which at the same time initiates the next action. Some of these relays indicate in this way that they are released, but this is the desired result of those actions to be indicated. It corresponds with clauses 1 and 4 of the requirements.

Action No. 3 corresponds with clause 5 as far as relay WKR is concerned. Action No. 7 corresponds with clause 3 as far as the relays RZR 2 and 3 are concerned.

The sequence of operated elements in action 11 of table 1—from the motor running up to contact m 2 changing—is another good example of meeting clause 4 of the requirements.

It should be noted that the sequence of the various actions which is forced by the contacts and required for functional reasons checks nearly automatically all actions upon their proper completion. Only four contacts are provided specially for checking purposes; they are not required functionally.

For example, the detection relay WKR is proved down for the fifth action. This proving is necessary as only a released relay is able to give an active indication that the points are in the end position. Similar considerations apply for the repeat relays of the position relays. It cannot be established functionally whether or not the pairs of latched relays change. Therefore, during the seventh action, it has to be proved that the positions of RZR 2 and 3 correspond with the position of RZR 1. Likewise the trailing indication relay TrKR has to be down before the detection is restored since otherwise a run-through would be indicated which in fact did not happen.

Another result of this forced sequence of actions is that only relay WR has to be equipped with heavy duty contacts.

The proving of a track relay should also be mentioned as an interesting example. According to the requirements, a block signal which has been passed by a train can only be cleared if the protection of that train by the next signal has been checked. If the track relay of the section ahead of the latter signal does not drop away, that signal is not replaced to stop. Therefore the signal in rear cannot be cleared in spite of the fact that the section governed by this signal is no longer occupied. In this way the train remains protected by a signal showing the stop aspect and the failure is indicated.

In stations the circuits of the route release are designed so that they offer the possibility of checking the proper working of the track relays.

4. RELAY CONSTRUCTION

The examples have shown that checking of contact position is not only required to prove the capability of work of the relays; it is also functionally required. Since every now and then the position of the contacts is established by the position of one of them, the relay has to be provided with rigidly-coupled contacts. Furthermore, the newly-developed safety relay is no longer equipped with pivot bearings but with an edge bearing. The contacts themselves are designed as double-break contacts. Only the contact bridges, which are firmly connected to the armature, follow its movement. This method has proved to be very satisfactory, as with the double contacts not only the contact gap but also the breakage speed has been doubled. The arrangement of the contact springs in relation to the moving direction of the contact bridge provides for a rubbing action of some tenths of a millimetre. Consequently the contacts wipe clean; the movement is also damped which prevents contact bounce. In the new relay the pressure of about 22 grammes per contact in the down position is obtained from a spring and not, as in previous designs, from the weight of the contact bridge and support at rest. This spring is, however, operated at such a low load that breaking seems absolutely impossible. Even if breakage occurred the remaining weight would be at least sufficient to operate the contacts, although not, of course, with the normal contact pressure.

A widely argued question is the use of silver-to-silver contacts. This material has proved to be very good in all cases dealing both with very low voltages and relatively high currents. Moreover the resistance of silver-to-silver contacts is very low, which is an advantage indeed, especially in the circuit technique discussed requiring so many contacts in series. Finally it is well known that the oxide film which might arise owing to a heavy load is also conductive. This of course affects the reliability of these contacts favourably.

4.1. Contact Materials

In practice relay contacts may weld together. This does not only apply to silver-to-silver contacts, but also to silver-

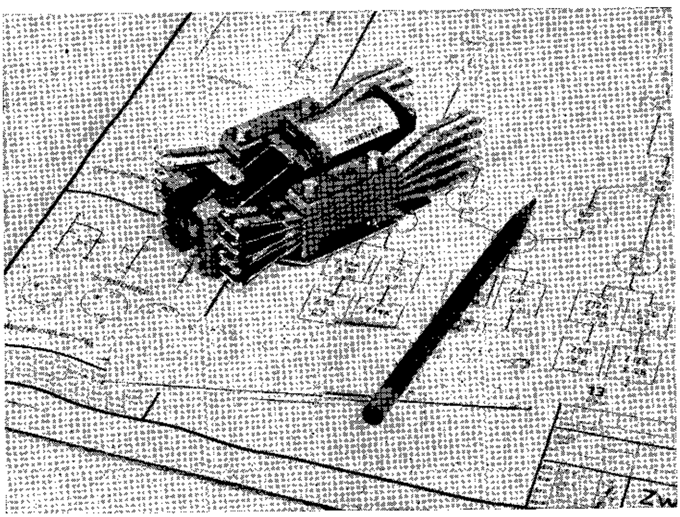


Fig. 2. Miniature type safety relay.

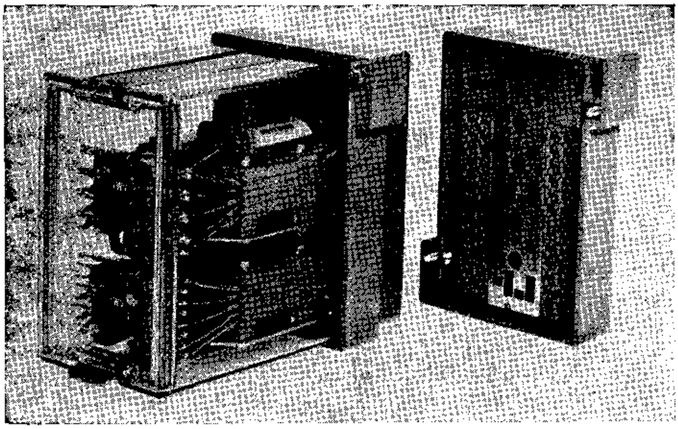


Fig. 3. Pair of latched relays. Plug-in design with dust cover.

to-carbon contacts. However, welding can only occur in very limited and unusual circumstances, which simplifies the preventive measures.

Fig. 4 represents a relay of which a silver-to-carbon contact has welded. It is the second contact in front. Unfortunately the picture does not show whether the other front contacts are still closed or are already open. However that may be, the armature is stuck in the attracted position. The exceptional event causing this to happen was a lightning strike. Considering the many heavy thunderstorms in tropical countries, this failure possibility is not to be ignored.

As already said silver-to-silver contacts can weld together. Many trials have shown, however, that here also only rare circumstances result in the welding of contacts, such as when high peak-currents occur at the closing of a circuit (owing to the discharge of condensers for example).

Accordingly special care has to be taken of circuits with condensers. The conditions under which welding may occur can be suppressed easily by the installation of relatively small protective resistors. The use of silver-to-carbon contacts for quick acting relays is not recommended because of the high rate of wear. The latest design of miniature safety relay is a quick-acting relay of this kind. Investigations by the Swiss Federal Railways of this type of relay as a track relay led to a decision in favour of silver-to-silver contacts.

4.2 Prevention of Sticking

The condensers used for the slow release

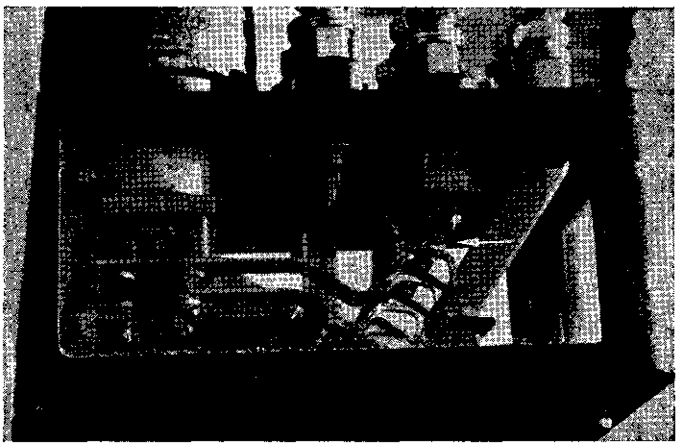


Fig. 4. Shelf-type relay with welded carbon-to-silver contact.

of relays are provided with a series resistance. Its value is 50 Ω when the condenser has a capacity less than 500 μF, and 100 Ω when the capacity is more than 500 μF. Welding trials have shown that even without these protective resistors it is extremely difficult to bring about welding of contacts. Only a momentary sticking could be achieved. Therefore the provision of these series resistors is sufficient to prevent welding completely[2] Nevertheless the relays are proved in many cases since there are a great many other reasons for the sticking of a relay. I need only mention here the possibilities of stray-currents, short-circuits and earth faults, which could have the said effect. Obviously such faults may originate in the first place in cores of cables running from the relay room into the yard. An additional failure possibility is a broken wire, which however is easily detected.

5. CHECKING CIRCUIT CONDUCTORS

The point control circuit already mentioned also provides a very good example of the checking of the conductors. The four cable cores running to the point machine are so connected that any of the failures mentioned, except the broken wire, in a certain combination, leads to a short-circuit. In this way the failure appears definitely, as one of the automatic circuit breakers will operate or a fuse will blow. Broken wires are of course indicated by cessation of detection (relay WKR drops away).

In order to provoke a short-circuit if one of the failures occurs, both power sources, for detection and control respectively, are earth-connected and alternately switched to the cable cores. So, once during the whole operation cycle, each of the conductors will have a potential difference to earth or to the adjoining conductor.

To test a circuit for the correct implementation of all these postulates more than 200 combinations have to be checked if any change is made in the circuit design.

Obviously there are also possibilities of offering protection by constructional methods. I refer to individually-screened cable cores or to the installation of fixed wiring under a protective cover in a relay set which prevents any damage of the insulation when the set is handled. The principle of failure indication by withholding a permission which in itself could be given, naturally affects the operating reliability of an installation in favour

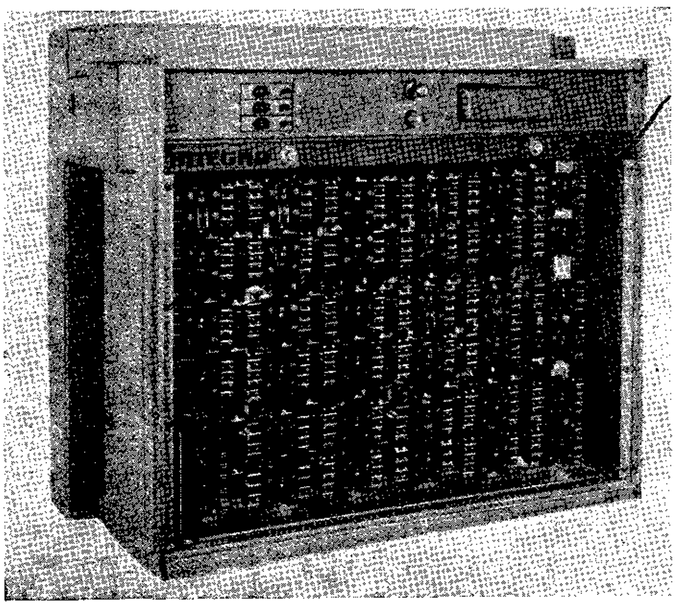


Fig. 5. Plug-in unit for point operation and control.

of safety. Therefore every effort must be directed to ensuring maximum reliability of the separate components. Accordingly maintenance is very important.

6. MAINTENANCE

The normally loaded contacts of the relays can stand 10^7 operations without any essential changes requiring attention or even overhaul. In our normal practice the first inspection is carried out after two years of service, even in stations with dense traffic. It is limited to a visual inspection of the relays and if necessary a light cleaning of the contacts. Until now actual overhaul is only carried out with relays of the older type. These relays have more moving parts and are therefore more susceptible to faults. Nevertheless here the first thorough checks have been deemed necessary after 5 to 10 years. Relays put into service some 30 years ago have been operating ever since without any failure. Only now are they going to be thoroughly overhauled.

Although the relay is rather small it is very sturdy. Still better results can be expected from the new type of relay as it is designed without hinges or pivot bearings. It is hardly necessary to point out the favourable effect on maintenance costs and staff requirements. Still more can be expected from components without moving parts. This might be the reason why in the railway signalling field, trials have been undertaken of the application of these components on a bigger scale, although these solutions at the present time are generally more expensive than with normal relays.

Apart from the high costs there are also difficulties of another nature.

7. ELECTRONIC COMPONENTS AND CIRCUITS

Considering electronic components (with the exception of ferrite-cores), we find them sensitive to voltage peaks, overload and higher temperatures. Partly this can be overcome by the use of silicon as raw-material. But all these elements have the disadvantage that in case of a failure they will take on an indefinite resistance, which also may possibly vary. The back contact of a relay is however either closed or open i.e. the resistance of the switching point can only be one of the extremes, either practically zero or infinite.

The form of grouping of contacts within single relays is such that proving of the position of these contacts is satisfactorily achieved by the use of a single contact within the relay assembly. The form of static components does not allow a similar proving feature to be used. Also the properties of these static components do not allow connection in series, as is done with relay contacts. Certain circuit combinations, such as flip-flops, assume an arbitrary condition after restoration of power following a power failure.

Only an incomplete survey of the properties which make special measures necessary for using static elements in railway signalling has been given here. One of the possible measures is duplication of components, i.e. two systems have to be made, which operate in parallel in such a way that in the intermediate and final stages comparisons take place. Thus about the same effect is achieved as from the requirement for the relay, that each failure has to indicate itself, preventing a dangerous situation arising from the combination of two failures. The measure suggested for electronic equipment is not very economical, so that it is better to decide the best measures according to the individual circumstances of each case.

The electronic axle-counter provides such an example. This device uses flip-flops for binary counting. So for each power of two a flip-flop is available. The circuit is designed so that the flip-flop counting chain is able to count forward as well as backward, i.e. the first pulse generator causes forward counting, whereas the second pulse generator (where the train clears the section) causes backward counting.

If, now, the 3rd counting stage were defective for example, then with a train of 12 axles 8 would not be counted. So the counter would be restored to zero, although the train did not leave the section completely. Thus the "zero" indication of the axle counter would be faulty. To prevent this an artificial count-down step, followed by an artificial count-up step are made when the "zero" position is reached and the exit track is cleared. This means, however, that from 0 back to 255 all elements have to operate

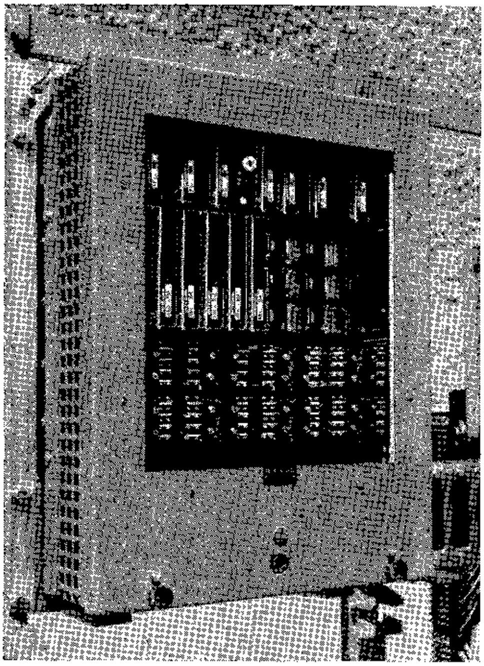


Fig. 6. Axle-counter register.

in the backward direction. With the artificial step from 255 to 0 all elements have to operate in the forward direction. On this occasion a defect would show itself. So only after this operation does the " zero " indication become an actual " line-clear " indication.

Another requirement which has to be met must also be mentioned, namely that the counter can only indicate a real " zero " when it has been confirmed that it once left the " zero " position and afterwards returned to it. This is similar to the requirement already mentioned for the block signals in connection with the track relay.

This example shows that for electronic circuits, also, the operational capability of the whole system can be proved. However the method has to be adjusted to each individual case. A simple rule, as for relay circuit design, cannot be established[3].

It must be mentioned that from the railway signalling point of view, ferrite-core switching elements have essentially more favourable properties than the other electronic components. One defect can be a wire breakage which results in continuous closure of the switching element. This can be checked, however, without difficulty. Another defect may be the fracture of the core itself. In this case the core is no longer able to switch.

With ferrite-cores, also, temperature must be considered since above a certain temperature the properties change.

The ferrite-core has also a very desirable property : it is not operated by a continuous flow of current but by pulses, i.e. there is practically no time limit for the core remaining in the excited position. This property is similar to that of the latched relay, which plays such an important role in the circuitry of our type of railway signalling installations.

Ferrite-cores also provide the possibility of checking. This is shown by the circuit for the transfer of a train description from one display to the other. If one of the figures of the transferred description is wrong, incomplete or illegible, the first display is not cancelled, but the figure

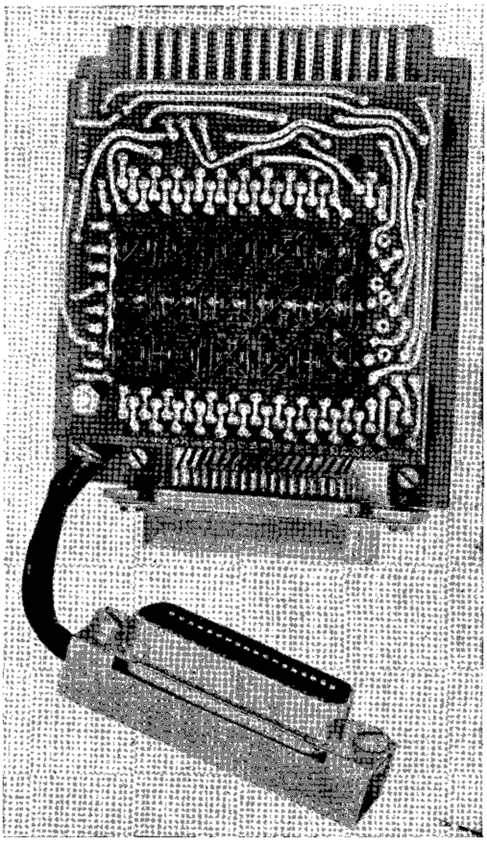


Fig. 7. Ferrite-core memory.

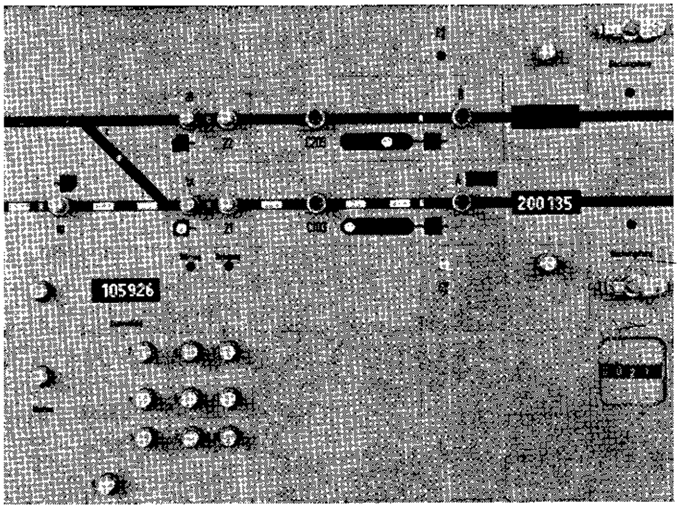


Fig. 8. Train describer display.

concerned flashes thus indicating its faulty transfer. Again it must be said that no general rule can be given for checking.

7.1. Maintenance of Electronic Devices

With the use of electronic devices the question of maintenance is also important. In actual fact, electronic components have a reliability some powers of 10 higher than that of relays with movable parts. This seems to offer the possibility of reducing maintenance even more, thereby bringing down maintenance costs. However, this does not change in the least the necessity to prove the functional ability of the devices in such a way that when failures occur they indicate themselves immediately, i.e. tend to the safe side.

Therefore it is not permissible to compare the use of such components in different means of transport, without knowing exactly the conditions of service. For example, in aviation the aircraft equipment as well as ground equipment repeatedly undergo very minute checking. This much reduces the time available for a failure to occur compared with the time calculated according to probability. So here a concession is made to probability concerning the first occurring failure, whereas in railway signalling technique this concession is only made for the second failure which can occur, when the first failure has already indicated itself. Another reason why railway methods cannot be applied in aviation is that at the occurrence of a failure it is most undesirable to stop an aircraft.

Furthermore it would not be possible to consider such a minute maintenance service on the railways. One has only to compare the daily number of aerodromes approached or overflown with the daily number of operations on a railway system. Maintenance as carried out in aviation, concentrated at a few places, would be absolutely prohibitive for the many elements spread over a whole railway network.

The calculation of so-called "safety" may be justified in aviation but it is not permissible to apply it to other means of transport without considering the completely different nature of the circumstances.

In connection with maintenance it might be worth mentioning still another point of view. The number of failures actually occurring in installations merely equipped with relays is extraordinarily small. There are installations and devices that operate for many years without any failure. But this also means that there are too few opportunities for the linemen to become, or to remain, familiar with the circuitry.

This phenomenon is still more evident when electronic equipment is used. Maintenance is, of course, much simpler as faulty electronic circuit elements are

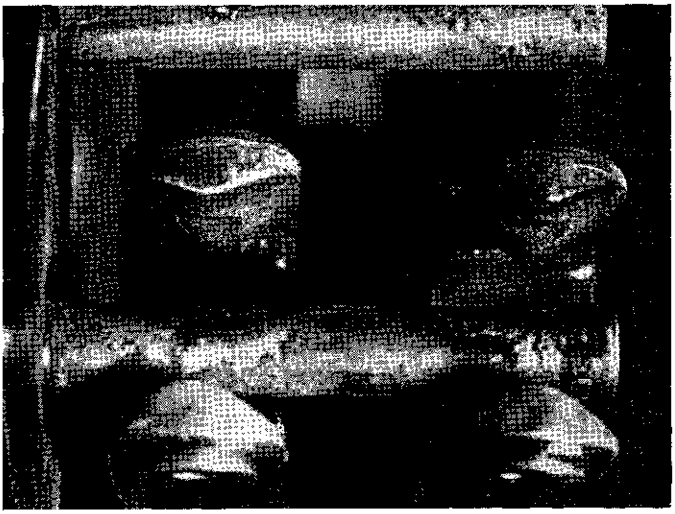


Fig. 9. Silver-to-silver contacts of miniature type relay after 10^6 operations on three lamps, 40 V, 20W in series, with operating current 0·46 A. On open contacts 115V; peak current 1·84 A when contacts are closed on cold lamps.

thrown away. This is facilitated by the use of plug-in elements which are kept in stock. On the other hand there is the need for people who know which piece has to be thrown away, and who have the opportunity to maintain their experience by means of exercises. Portable devices with explicit instructions for their use should be manufactured as an aid to staff in finding defective elements.

8. CONCLUSION AND ACKNOWLEDGMENT

It is obvious that the examples cited here and the comments upon them do not answer all the questions concerning Continental practice. But I hope to have given you at least an idea of some of the problems and the principles applied.

I would like to take the opportunity to thank our President, who suggested this paper, and all the people who helped me to prepare it.

FOOTNOTES

(1) This relay TrKR in series with the high-resistance coil of WKR does not pick-up by the normal flow of the detection current. When the points are trailed one of the motor contacts changes, cutting out WKR and providing a direct path for the current through TrKR which will pick up.

(2) With contact resistance 0.25 Ω a "welding" of contacts can occur when

$$\int i^2 . dt \geqslant 10$$

The control and detection circuits are protected with fuses of 4 A pre-arcing constant, which corresponds with the value $I^2 . t = 5$, when $t < 10$ msec. So the fuse would blow before the critical value for the contacts is reached.

In order to prevent positively the the blowing of the fuse in parts of the circuitry containing condensers, with a maximum voltage of 56 V and $\int i^2 . dt = 1$ a protective resistor is required of $R_\Omega > 1{,}5 . 10^{-3} C_{\mu F}$

(3) It will become a major problem to observe the established principles of railway signalling technique when the transmission of information from the track to the locomotive, and its interpretation, with corresponding indication to the wayside equipment, have to be incorporated in the system of safeguarding train movements.

DISCUSSION

Mr. J. F. H. Tyler said it was a great privilege to open a discussion on a paper given by Dr. Oehler, who was a very old friend of the Institution. He had introduced them to new designs of signalling equipment and those who went to his factory at Wallisellen or to the one at Vevey would see examples of the highest class of workmanship, and of the careful attention to detail he had described in his paper. He had only taken two items of equipment in detail, the point machine and the relay.

The point machine, a typical Continental type, economical in line wires, was neat and tidy in design, and quite an object lesson for those who had used the American type.

On relays the same thing might be said. They were, he supposed, in official disagreement with Dr. Oehler in regard to metal-to-metal contacts. It was a great step to drop the carbon-silver contact, but nevertheless it would have to be seriously considered. There was no doubt, that if they were able to adopt metal-to-metal contacts, they could have a much smaller relay.

He asked Dr. Oehler two questions. The first was whether one could reverse the direction of movement immediately in the event of there being an obstruction in the points. He had understood that after a time interval it could be done, but was not clear that it could be done immediately. The other question was whether Dr. Oehler had given any consideration to the use of Alkanite as a metal contact.

Dr. Oehler thanked Mr. Tyler for his kind words about their factory. Of course, they were doing their best and he hoped this best was reflected in the reliability of their relays and other items they made and applied for railway safety.

With regard to reversing the movement, he had mentioned that after the two latched relays Rst1 and LZR1 had changed, it was possible to release the push-buttons because these two relays now held the order given. Of course, to effect this took much less time than to explain it. After the time needed for a few relay operations, the push-buttons could be released. One could operate the push-button again any time during the run of the motor. At that moment, the circuit for the relay RL was open and that for RR was closed. RR up released JR and that in turn WR. RZR1 picked up and LZR1 was coming down. This meant that at once these two relays changed the connection between the outside feeder and the motor so that it could start to run in the other direction. It could be done any time and as often as required. Reversing was always possible. It must be mentioned that by the conditions given for the relay WR, which connected the motor to the feed, there was no change possible with the relay WR up except for relays RR or RL and JR. This meant that there were no other contacts changing under the load of the motor except those of WR. Only relay WR was equipped with heavy-duty contacts, all other relays had ordinary contacts.

The material of the contacts was silver. Some other materials had been tested but the results were not much of a success. Since these silver contacts had a very low resistance, they did not think of abandoning the silver contact. He did not think it worth while to change to another material.

Mr. B. Reynolds said the title of Dr. Oehler's paper was amply born out by the contents and like the President's paper of the last session he dealt with very deep principles rather than practice. It was often said that the principles of fail safe could not be recorded but he felt that the summary in paragraph 3 had recorded not only the precepts of safety but the means of proving safety. He apologised to Dr. Oehler for introducing a topic which was not in his paper, namely pre-selection. When pre-selection was in force and there were two or three routes stored in signal apparatus to be sequentially released without the intervention of the signalman, it was understood that the integrity of the track circuit must be guaranteed, and he would like to know if Dr. Oehler had any views on the best way of achieving that. He would be particularly pleased if he would give some examples of specialist treatment of track circuits rather than examples of some of the other two or three ways of achieving the integrity of the route.

Dr. Oehler mentioned the use of solid state devices and suggested that their use was not yet proved to be quite as reliable as the rest of the normal conventional signalling equipment—how true that was! Many pitfalls lay in wait for traders outside the regular signalling profession who offered solid state devices for testing on the railway. One of the pitfalls was temperature drift, and in tests conducted by the B.R.B. they had an instance where tests of some solid state equipment involved the use of an inductive area in the track which was tuned into resonance with a reference frequency by means of an adjustable capacitor. This could quite easily be done and when resonance was achieved with the track clear the track relay duly picked up.

They did not know at the time that the tuning was very much too sharp for the particular piece of apparatus being tested, and neither, he suspected, did the manufacturer realise this. The condition obtained that during the cyclic temperature drift between day and night the unit would go off tune very quickly and in next to no time would be showing an apparent occupation when in fact no vehicle was on the track. During the night on one occasion a wandering technician spotted that there was a relay de-energised and no vehicle on the track and re-adjusted the capacitor to pick up the relay again. After dawn the next day the relay very properly dropped out because the temperature drift had corrected itself, but during the resumption of tests the presence of a vehicle on the inductive loop proved to be enough to give the precise retuning of the loop which accorded with the reset capacitor, and the relay therefore promptly picked up with the vehicle in section. That taught them to be very careful of temperature drift in connection with solid state devices.

Dr. Oehler also mentioned ferrite cores, perhaps with the thought that they were somewhat more trustworthy, but here again pitfalls lay in wait for those who had not used ferrite cores for very long. On one occasion a ferrite core demonstrated to B.R.B. contained a coil which had to be kept energised. It was some years ago and now the exact reasons for this escaped him, but it could possibly have been that when the ferrite was kept saturated the core cycling condition was suppressed. The significance of this crucial normally-energised coil was appreciated by the manufacturers and they went to some great lengths, with special formers and special windings, to see that no turn should ever touch another turn inside the coil, and in the finish they potted it. Having triumphantly produced this coil they *then twisted the two outgoing leads together* thus nullifying completely the effect; which went to show that however deeply rooted the principles of fail safe might be it could come to grief on quite a minor incident of practice.

Finally, he suggested that such a paper as this was not only very difficult to write but could only be based on many, many years of facing failures and overcoming them. Once again he would refer them to the precepts set out by Dr. Oehler in paragraph 3, which he felt must without doubt be of benefit to them all.

Dr. Oehler said he had expected the question of track circuits would come up and therefore he said in paragraph 3 that the proving of the track relay should also be mentioned as an interesting example; and a little later on, he had said: " in stations, the circuits of the routes are designed in such a way that they offer the possibility of checking the proper working of the track relays ". He must say here that in practice these principles could be followed or not; this was just a question of the responsibility the man in charge was willing to take. The man in charge in this instance was the chief engineer of a railway, who had to deal with such questions.

For example, checking of track circuits was not the practice in Switzerland; up to now it just had not been proved that the relay could stick. But now, with the new practice of preselection of routes, checking was absolutely necessary, not only for proving, but also for the operation itself. For instance, a route might be set, say from right to left, over points, and then a route was preselected, at that moment, in the other direction, over the same points. If the train—or just a locomotive—was going over the points, then the first route was released; and the train or engine having moved a bit further, the other route was automatically established. Without the use of special means, this movement would at the same time also release the preselected route, so preselection would be gone. Care must be taken that the release of a route was only executed by a movement beginning at the signal and going in the correct direction to its end, and if one of the track circuits did not operate, i.e. if a relay stuck, the route was not released any more. So in actual fact this had to be done for the operation, and not for checking. The feature could be easily achieved; suppose, for instance, that a track relay could not pick up unless one of the neighbouring track sections was occupied.

As to the question about ferrite cores, it should first be mentioned that a ferrite core was a switching element which switched in the wrong sense. If there was d.c. on, then the " contact " for a.c. was open, and if d.c. disappeared, then the " contact " for a.c. was closed, and that was just the opposite to what one normally was used to. But it was possible, again, to prove this because ferrite cores were in fact transformers, and they could be operated in such a way that the d.c. for switching was produced from the a.c. which was transformed. In this way, one again had proving.

Such a ferrite transformer was used for checking signal lines. The current for the checking relay for the signal lamp circuit was provided by the secondary winding of a ferrite transformer. This current could be cut by exciting the ferrite transformer with d.c. Two coils were provided to perform this d.c. excitation. One of them was fed through a rectifier from a checking lamp located on the relay rack; the other was fed through a rectifier by the current of the signal lamp. The coils were connected in such a way that they excited the ferrite transformer in opposite directions. Therefore, the lamp current was compared with the current in the checking lamp. If both lamp circuits were in order, there was no d.c. excitation on the transformer and the armature of the relay was up. In case of failure—for example, if a short circuit bridged the filament of the signal lamp—the compensation was destroyed and the " contact " for the proving relay was open. But this would not be the case if the current for both lamps should fail at the same time. Therefore, the primary windings for the proving relay were connected in the a.c. circuit of the proving lamp.

Mr. M. E. Leach said he was always filled with admiration at their friends from the Continent who came to this country and gave such excellent papers in foreign languages, and he always hated to think what would happen if the position were reversed and he had to try and produce a paper of the excellence they had just heard in another country's language, let alone answer the discussion afterwards. He congratulated Dr. Oehler on such an excellent paper.

He was particularly interested in the question of contact welding because some years ago he was intimately connected with some experiments which his Region carried out when the possible use of relays with metal-to-metal contacts was being considered for vital circuits. He was, therefore, very intrigued by the photograph, Fig. 4, of a conventional shelf type relay with an apparently welded front contact. Could Dr. Oehler give some details of the circumstances in which this occurred because it was his understanding that carbon was completely unweldable. The reason for this was that carbon did not have a liquid phase like a metal, but went straight from the solid to the gaseous state at a temperature of something like 5 000°C, and he therefore wondered whether in fact the contact material in this particular case was carbon impregnated with silver. This was a practice adopted in this country to reduce the contact resistance of pure carbon contacts. They had been very surprised to find that some of the silver-impregnated carbon in use in shelf type relays contained as much as 50 per cent of silver and they were very frightened when they started experiments with this material that the silver would melt and run out of the carbon to form a molten mass which on solidification would cause the contacts to adhere. They found, however, that the molten silver was retained in the porous carbon by surface tension, and if the carbon continued to be heated by the fault current, its low thermal conductivity caused the temperature to rise sufficiently to volatalise the silver.

As far as metal-to-metal contacts were concerned, after some experience they found they could weld these almost to order, in the following circumstances. If the contacts were closed so as to short circuit a source of power with a fuse in the circuit, and the various parameters in the circuit were critically related, sufficient current passed when the contacts closed to bring the contact elements up to a temperature at which they would soften, forming a slight molten area at the point of contact. If, then, the current was cut off by the fuse blowing, the metal contact solidified and one was left with the contacts welded. This was a very complex phenomenon and the relation between the conditions required for it to take place were very difficult to specify.

Another form of welding occurred with metal-to-metal contacts where critical bounce was present when the contacts closed. An arc was struck when the contact re-opened after the initial closure, and if this was sustained long enough whilst the contact was open, sufficient local melting took place because of the high temperature to cause the contacts to stick on the second closure. He thought, as had happened in Switzerland, that they found this occurred in circuits where capacitors were charged up through contacts closing or where there was an initial surge of current through the contacts as in the case of a lamp with an initially cold filament. Needless to say, some of the conditions under which they welded contacts were not very practical—that was to say, they were not the sort of situations which would occur in service. Nevertheless, he would be interested to hear Dr. Oehler's comments on these points.

Dr. Oehler regretted that he had no exact details about the contacts and the contact material which were shown in Fig. 4. It was quite possible that these were contacts of carbon with silver. It was a lightning stroke and it might be even possible that here the carbon contact was just blown away, and then it was metal-to-metal, but he did not know if it was what happened. Once he wrote a short paper in *The Railway Gazette* about these weldings, with the use of silver-to-silver contacts, just to initiate a discussion. He was sorry that this discussion did not develop. The only reaction he got was this photograph. He could not say anything about the conditions which caused this relay to stick up; all he could say was that it did so.

Now to the question of silver-to-silver contacts. They had made quite a number of tests with these contacts and found that the energy produced at the contact at the first moment (before the heat could spread) was responsible for welding. It was only a question of bringing this energy down to a level which prevented welding. For example, they figured out what was given in the second footnote: the energy given by the formula $\int i^2 dt$ must be more than 10 to get welding. They found that the amount of energy one got in a circuit with such a contact, when the fuse normally used blew on account of a short circuit, was still less than the above value, which meant that the fuse blew first, before the contact welded. Therefore, they found that the resistance which was really needed to prevent welding was rather small.

Another question was the contact design. The contacts of these relays consisted of two contacts with one silver bar, which doubled the speed of operation, and even bouncing did not do anything. They made tests with contacts which they loaded with a very heavy short circuit of 50 amp. They got just two arcs and since the current had to go round in a half-loop, the two arcs were just blown away; the contacts were destroyed, of course, but the circuit was unmade. It was just a question of experience, or the question of preventing it by—as had been said—designing the circuit in such a way that it would not happen. If one could prevent the circumstances, then the welding of contacts was impossible.

Mr. E. A. Rogers said he was glad to compliment Dr. Oehler on his very excellent paper which dealt with a subject of very great interest to many of them at this time.

There were one or two points he would like to make. Right at the beginning of the paper, in the introduction, and on the first page, was it intended to suggest that safety was only introduced at the stage when the Signal Engineer took over the complete responsibility from the Operator by introducing either remote control or control by train description? Surely any modern signalling installation giving the signalman control of his traffic by means of power must have safety built into it right from the start. The other features of remote control, or control by some form of machine or train describer, should come after safety had already been built into the system.

In paragraph 6 Dr. Oehler referred to the maintenance of relays with silver contacts and to a practice which, he believed, was used in many Continental countries, but had always been strongly opposed in this country; that was the ability of a lineman or maintainer to open the relay and have access to the contacts so that he might clean them. What were the limits of his permission here? Some of the photographs showed contacts after testing which were quite badly burned; was he allowed to try and smooth up the surface of that contact when it got into such a condition, thereby possibly producing a fair amount of silver dust; and what was the possible reaction on the contact pressures and gaps if he was allowed a free hand with his cleaning tools on the contacts of a relay in service?

In paragraph 7 Dr. Oehler quoted, if he remembered rightly, reliability of electronic equipment of some one order higher than conventional equipment. Was this comparing an electronic component with, for instance, a relay, or was it the total reliability of the equivalent large number of electronic components which would replace a conventional multi-contact relay?

Dr. Oehler, answering the question about responsibility, said he thought they were all agreed that the work of man was not safe and if one furnished the man with a machine that took over a certain part of the responsibility, then for the rest one still did not have safety. Therefore, only if one took away from him all the work, and the machine took over all the responsibility, could one say that the installation was safe. Of course, it was often not possible on account of the cost to make a machine which could do everything for every small station. How far to go was a question of the diversity of the task the man had to accomplish. If he was at a small station he had not very much to do and could take care of his actions which were connected with train movements. As soon as the man had too much to do, his burden got too heavy and one must give him a machine which took over the responsibilities more and more, until the responsibility was entirely with the machine.

Once on a network of private railways in Switzerland a man forgot the crossing of two trains, entailing a very bad head-on collision. The station was equipped with an interlocking machine, but not with lock and block on one of the approach tracks. So the Federal Railways Board in Switzerland said: " We should really make a lock and block between stations everywhere, because such a thing could happen at any time. But this is not possible, because there is not money enough available for doing it ". So it was then a question of calculating for which locations it really was a necessity, and in which it was not. They established a formula based on the type and number of approach tracks to a station, the number of trains per hour of maximum traffic, the speed of the trains and also the number of trains running in the 24 hours. By addition and multiplication the formula gave an index. Then this calculation was made for every station on the private railway systems in Switzerland and it was found that the particular station where the accident had happened appeared as No. 7 on the list of stations. This was proof that here it was necessary to install block apparatus. Moreover, it was not only found necessary to install the block on lines with heavy traffic. For example, at a station with branch lines, lock and block must be installed on all approach tracks, even on those with little traffic.

On the question of maintenance, Mr. Rogers had asked what did the man do when he opened his relay, and what was his duty. Well, the first thing was that he checked the contacts. It was for this reason that all contacts were in the front and accessible. He might find that one of the contacts required cleaning, and so he cleaned it using some very fine paper. This could be done without affecting the contact pressure.

With regard to men who were no longer accustomed any more to this type of circuitry, it had been found that maintainers at some stations were actually afraid of a failure because they felt they were no longer experienced after having had no failures for many years. Obviously, they had failures with track circuits, perhaps on account of poor ballast. but not in the electrical equipment. With electronic devices, however, this could be much worse.

If he had said electronic components were more reliable by many powers of 10 than relays, he had been thinking of the moving parts in relays. This meant that relay type apparatus was much less reliable than apparatus which had no moving parts, of course. But he never had in mind the reliability of a whole system.

Mr. H. H. Ogilvy said every time the question of fail safe was discussed with a Signal Engineer he got the reply, more or less, that the possibility of a wrong side failure did not arise; in other words it never occurred. But he could not accept the fact that a wrong side failure would never occur although he would accept that the chances of this were very rare, although, as Dr. Oehler had pointed out, there was always the human element and if one was talking about safety it seemed to him not quite correct to talk about the safety of the equipment, which was very, very high, without bringing in the question of the failure rate of the human element. For example, if one considered the locomotive driver, one must ask what was his failure rate? How many times did he pass a signal at red? It was no use saying he never passed a signal at red. He was sure some drivers must, once in their lifetime, pass a signal at red, and it could be worked out fairly easily that if a driver passed merely one signal at red in 25 years of driving on a main line, this represented a failure rate—a wrong side failure rate—of 1 part in 10^4; and they were putting this man in parallel, it could be said, with equipment which, according to the Signal Engineer, had a wrong side failure rate of one part in ten to the power of infinity. This did not seem to him to make common sense and he would like to ask Dr. Oehler to comment on it. Perhaps his comment would be: " Oh but we put other things on the track to supervise the driver. For example, we put automatic warning systems on the track and this, taken together with the driver's failure rate, gives a much lower failure rate." This he would accept but he submitted that it was introducing redundancy into the system.

Dr. Oehler said that in answering this question he would just repeat that man was not safe. He was not safe not because he sometimes made an error, but because his errors were not always on the safe side. If a driver would, say in 25 years, once stop ahead of a crossing he would say he had made a failure on the safe side, but that did not count; he had the means to distinguish the consequences and that was the difference between the apparatus and man. Apparatus was not reliable in that sense either, but one accepted it because it could be made in such a way that an error was always on the safe side—that was the difference.

Mr. Ogilvy replied that he was not sure that Dr. Oehler had quite got the point he was trying to make. He felt that if a driver had a wrong side failure rate of 1 in 10^4 this was when he actually passed a signal at red—not when he misread a signal, which might occur more frequently—he did not know. But if there was the possibility of one part of the system—in this case the driver—having a failure rate of 1 in 10^4 on the wrong side, he still could not see why it was necessary to produce equipment which had a failure rate of 1 in 10 to the power of a very large number approaching infinity. He could not see that the two together made sense because the actual overall wrong side failure rate, he must emphasise this, the actual overall failure rate was 1 in 10^4 in the case of the driver plus 1 in 10 to the power infinity, which was near enough 1 in 10^4. So he was still asking the question, were they paying too much for safety which they were not getting? At least mathematically they were not getting it.

Dr. Oehler said he now understood Mr. Ogilvy's question. He had said it was not only the driver who could make errors on the unsafe side. If one had an installation which did not go to the lengths of being what they called a safe installation, because some responsibility remained with the man who operated the train movements, there one had the same thing. But if one gave him an apparatus on which he should rely, one must give him something which was " safe ". The man relied upon this device completely; he did not think any more if his actions might be unsafe. He just acted and left the responsibility entirely with the apparatus. Therefore, this apparatus must be much more than just reliable—it must be safe. If the man found out that the apparatus was not far more reliable than himself, he would find himself in a very awkward position. The responsibility was either with the man with low reliability, or with the machine with reliability near infinity.

Of course, a driver at the head of his train, travelling at high speed, had a rather high responsibility, but he was aware of this fact. If they tried to give him a device taking his responsibilities, it must be such that he did not need to take care of everything any more. This meant that they helped him in a safe way to watch the signals. This had been realised by the automatic train stop, but up to now it had not been considered necessary to interfere with the driver's actions. If they completed the apparatus in this respect also, they arrived once again at an apparatus which must do its job with safety, not only with reliability a few powers of 10 higher than the man. Not with a failure rate of 1 in 10^5, or 6 or 7 or so —it must be *safe*, and that meant automatic driving. Again it was a question of judgment if the expense for such devices was necessary and justified.

Mr. J. P. Coley said some years ago he had the privilege of being able to study the type of relay which Dr. Oehler had been talking about under the actual tuition of Dr. Oehler, and he also studied a similar relay made in Germany. At that time he became permanently convinced that the type of relay they were using on the Continent, with silver-to-silver contacts, was in fact safer than the carbon contact type of relay commonly used in this country. The reason why he became convinced of this was because the relay was, of course, proved to have released in all the essential circuits. But this in itself was not enough; It must be impossible for the relay to close its down-proving contact if one of the front contacts had welded. The Swiss and German relays were so constructed that this result was achieved.

He had listened to Dr. Oehler to hear him say something which would give him the impression that the relays he had been talking about had this safety feature in them, but he did not seem to say it in so many words in the paper. He had referred to the use of resistors to prevent welding but he (Mr. Coley) did not feel that one could depend on this alone for safety; only for reliability.

When all relays were proved to be down after operation and before the next step in the sequence was completed, one had an arrangement where a very cheap (and one might almost say shoddy) relay could be used. For example the bearings could be extremely elementary instead of the highly engineered types used in U.K. relays. If the bearing jammed, the down proving contact would not make and safety would be achieved. With British relays, however, despite the precautions taken over design and manufacture of the bearings, sticking of them was not unknown. He thus contended that with the foregoing safety feature built into the relays and circuits, one had greater security with a cheaper relay.

Dr. Oehler thanked Mr. Coley for what he had said because it gave him the opportunity of adding a few thoughts. They opened or closed a circuit always with two contacts connected in series by a silver bar which was moved by the armature. It was never possible for these two contacts to touch the silver bar exactly at the same time. Therefore only one of them was in danger of welding. If the conditions were such that one contact welded, the circuit would be broken anyhow by the other contact as soon as the relay started to return to its previous position; but on account of a welded contact even this position could not be reached any more, nor could all the contacts of the relay which stopped in an intermediate position stay open. Here he had to emphasize that they did not check relays to prove their own ability to work; they checked systems, they checked circuits. Any failure in the system, any part which was not in order, had to show up in the direction of safety.

The relay offered itself as a welcome means of indication. A relay which did not pick up or did not drop when it should, indicated a failure in the system which in most cases had nothing to do with that particular relay.

Since all failures showed up by preventing something which otherwise would be permitted, they were forced to make every piece of the installation as reliable as possible. This applied also to relays—a cheap relay which was not designed and built carefully for this purpose, could never accomplish its task. Apart from being of high quality, the relay should be so inexpensive that the designer of a connection diagram should never have to hesitate to use one additional relay in a safety circuit.

Mr. A. R. Brown said he would like to go back to a point raised about the human element in safety. They could design their signalling systems on the fail safe principle and certainly, to dispel any doubts on this, those who had worked in railway signalling for many years knew that wrong side failures did occur, very infrequently, but they occurred. They could design their circuits and make them so complex that if a wrong side failure did occur, then it became a wrong side protected failure. Perhaps one might say this was not now a wrong side failure, but having made them so complex then they increased the possibility of a right side failure and when they got a right side failure this meant that other action had to be taken to keep trains going. He could think of a particular line where they had quite complex circuitry to ensure that because there was two-way working, the A.W.S. system worked correctly and the magnets worked only for the right direction of traffic. Because of the complexity of this equipment it was not as reliable as it should have been and occasionally there was a right side failure. To keep the traffic working under those conditions one had to bring in emergency working with the human element. The human element did now come into the question. This was the time when incidents happened. So he thought they must consider this aspect. They must consider that there was a point where one could lose reliability for the sake of getting no possible wrong side failure, but because they did this they built into the system a more dangerous condition because of the human element.

Dr. Oehler, he knew, had a lot of remote control on his system. They considered that remote control was not safety circuits, so they did not build in against wrong side failures. This was virtually giving the signalman long arms, but when the remote control failed, again the interlocking at the far end was still there; but supposing the remote control asked for a function to happen at the remote interlocking when, because the remote control was out of use, hand-signalling was taking place there. What precautions did the Swiss Railways take in this case. Did they clip all points before they ensured that trains could move or did they rely on the indications that were now passing over the remote system.

Dr. Oehler replied that Mr. Brown had asked a very interesting question. If one accepted failures, but just did not accept failures on the wrong side, one increased the possibility of failures where the installation did not work any more in a certain respect. At such a time one needed some means whereby a man could intervene because the trains had to move. But it was necessary to bring to his attention the fact that at that moment he was personally responsible for that part of the installation now out of service, and if one had remote control, it was necessary to provide this safety at the end of the remote control. This meant that if the remote control failed, it must do so in such a way that the installation in itself could do its work if somebody went to the remote-controlled end and operated by hand on the spot. In Switzerland they had various places with remote control and it was interesting to note that the Swiss Federal Railways were satisfied to make it possible for the man to operate at least an auxiliary signal to keep the trains moving. It was a signal which showed, instead of the green light, an inclined row of yellow lamps looking like a yellow bar, and this told the driver he could proceed but must watch out himself. He could not go at high speed, but must proceed slowly and be prepared to stop immediately; but at least the train was moving, and in the meantime somebody could get to the spot and operate the machine by hand, when the train would again be safe. This was always a very important question when one had remote control, and he preferred to think of remote control as the prolonged arm of the man, and not a safety device. For this reason, S.F.R. officials thought it more important to make the remote control fail-safe for the information coming back rather than for the orders going out.

Mr. B. H. Grose drew attention to the splendid pat on the back Mr. Ogilvy had given the signalling profession by his figure of 10^4 wrong-side failures (he was sure it was 10^4 because he repeated it) in 25 years of main line driving. That worked out to approximately 400 red signals that a driver might have passed in a year, or roughly one a day for an average working week of six days. As the starting signal would be red at some time during the journey, this meant that the train would proceed without any impediment whatsoever to its destination, which seemed to him to speak very well of the present system and to strike a swinging blow at any superior systems he might be thinking about. He was sure that he must be wrong so would like to hear how Mr. Ogilvy arrived at his figure.

Dr. Oehler said he could imagine that it was possible to calculate a figure for the reliability of drivers, since their task had not a high degree of diversity. For instance, the station of Zurich to 1935 had no interlocking installation at all. There were men distributed on the ground, each of them in charge of about two or three ground levers for points. They never had an accident of any importance since these men did work of low diversity; but he could not imagine a man in front of say 20 levers without any interlocking between them. Since the diversity of the work signalmen had to do was much higher than that of the drivers, he thought it correct to give priority to providing safety devices for signalmen. Moreover, the reliability of men also depended on unpredictable events, such as something suddenly going against the ordinary routine of work at a certain time of the day, or a sick child at home—this could bring the reliability of a man down to a very low level.

The President said he was sure Mr. Ogilvy would like to speak.

Mr. Ogilvy said he pleaded not guilty and reserved his defence. A failure rate of one part in 10^4 was, in fact, very good. If one was driving a car and could swear that one's failure rate was only 1 in 10^4 then one was doing very well indeed. What that meant was that if one took a driver with a career of say, 25 years main line driving, and worked out the number of miles he did in a year and the average density of signals per kilometre, (say 1 per kilometre, on the main line), then supposing that only 5 per cent of these signals presented a red aspect, which he thought quite reasonable, then he passed one of those in 25 years. So if this occurred to one man once in 25 years his failure rate was about one in 10^4. He had said nothing about the other possibilities. They were only talking here about signal aspects, but the driver could also fail to do other things. He could fail to observe speed restrictions, and this brought in many other things which he was sure they did not wish to discuss that night.

The President, in closing the discussion, said the circumstance of Dr. Oehler giving his lecture had brought many thoughts to his mind—principally, of course, the Convention that they all so enjoyed during the summer when they were able to see for themselves the very high class system and workmanship of the Swiss Railway System. It was not his impression that the drivers on that system had a 10^4 failure rate by any means. He thought they were most efficient and obviously took a great pride in their system.

The paper that had been given by Dr Oehler was making history because they had all been aware of the great divide between the view in this country of the significance of fail safe and the way in which fail safe was regarded on the Continent. None of them would pretend that as a result of Dr. Oehler's paper and the discussion, the gulf had been entirely closed; that would be asking too much and was not to be expected. The important result arising from the paper and the discussion was a better understanding and appreciation of how the other person thought. The signal engineer today was faced with many problems; he was faced with new systems, not very far away, which in themselves were breaking entirely new ground and which had yet to establish how they matched up to the concept of fail safe. He believed the paper would help them all in taking a more considered view in the future of what fail safe was and how they were to interpret it. He then moved a vote of thanks to Dr. Oehler, which was carried by the meeting with acclamation.

The President then recalled that Dr. Oehler had been a supporter of the Institution for many years. In view of the great services that Dr. Oehler had given, the Council had thought it right that the occasion should be marked in some special way, and so it was with very great pleasure that he asked Dr. Oehler to accept an illuminated address which had been prepared recording the grateful thanks of the Institution of Railway Signal Engineers for the many personal services rendered to the Institution by Dr. Ir. K. W. Oehler on the occasions of the visits of the members of the Institution to Switzerland, signed 'President'. This address had been made by their Past-President, Mr. Horler, and showed at the top a magnificent view of the mountains of Switzerland.

He hoped Dr. Oehler would find a place for the address in his office in Switzerland, where it would remind him of his visit to the Institution that night, which he trusted would be recalled as a happy occasion.

Dr. Oehler expressed his thanks for the presentation, and the meeting was closed.

Overseas Provincial Meeting in Utrecht

The first Overseas Provincial Meeting of the Institution was held in Utrecht on February 23rd, 1968, and was preceded by a visit to the Rotterdam Metro system.

Some fifty members from England, headed by the President, Mr. H. W. Hadaway, sailed to Holland in the s.s. *Amsterdam* on the night of February 22nd, 1968. The next morning they were met by Continental Members from Holland and elsewhere, in the main hall of Rotterdam Central Station, whence the whole party travelled on the Metro to Rijnhaven Station. They then proceeded to the Rijnhaven Tramway Depot, where the visit to the Rotterdam Metro began.

During refreshments the party was officially welcomed by Mr. Tissot Van Patot, the Technical Manager of the Rotterdam Metro, who explained the municipal transport policy for Rotterdam in general and the existing and planned extensions to the Metro system, and how it is intended to integrate this system with the tramway and main line railway systems. He then gave technical details of the Metro, which had only been open for about two weeks, and stated that already 30—40% more passengers than forecast had been using the line.

Mr. Wassink, Signal & Telecommunications Engineer of the Rotterdam Metro, gave a detailed account of the signalling, telecommunications and automatic train control of the new line. His paper, illustrated with slides, explained that the system was an " automatic speed system with absolute permissive control," and the control was based on a time division multiplex system using five frequencies; by using two out of five codes, ten control codes were available.

The party was then split into three groups for a very full inspection of the rolling stock in the depot followed by a visit to the signal box, operating floor and relay room. A discussion followed, at which the Mechanical Engineer of the Rotterdam Metro joined Mr. Tissot Van Patot and Mr. Wassink to answer questions.

Seven members took part in the discussion, and the President, Mr. Hadaway, proposed a vote of thanks to Mr. Tissot Van Patot and his colleagues for the excellent visit which had been arranged. He stressed the fact that the I.R.S.E. was proud to be the first party to visit this new railway. The party then travelled, by courtesy of the Rotterdam Metro, to Masshaven Station, where the station control room was inspected. One of the main features here is that four television cameras are mounted in the station and the operator has a desk which includes four television screens.

The visit to the Metro terminated at approximarely 1.15 p.m. The party then travelled individually to Utrecht where the evening meeting was arranged; and after refreshments, which were provided by the courtesy of the Netherlands Railways at their Headquarters in Utrecht, the meeting began at 5.30 p.m.

The President took the Chair and opened the meeting by saying that this was an historic event in the proceedings of the Institution of Railway Signal Engineers, in as much as this was the first Technical Meeting arranged by the Institution on the Continent of Europe. After thanking Mr. de Vos, and through him, the Netherlands Railways for providing the accommodation, he called upon Dr. Oehler of Integra Ltd. to deliver his paper entitled, " Continental Practice and Policy on Fail Safe " (see page 114). This meeting was attended by 93 Members and visitors.

Mr. E. G. Brentnall, British Railways, who opened the discussion on Dr. Oehler's paper, said it was a great privilege to have heard it; to see gathered together in one unit so much information about the Continental philosophy for circuits; and to examine the detailed examples. He thought the British philosophy was really exactly in line with the Continental philosophy, in so far that mathematical possibilities against a wrong side failure condition were not accepted as standards by which equipments and circuits were designed. The British view was that the mathematical approach was quite inappropriate where the possibility of life and death was concerned. He thought the ridiculous analogy could be drawn with the game known as Russian roulette in England, where one put a cartridge into a revolver, spun it round and then put it at one's head and hoped for the best.

He was sure that very few signal engineers would be content to point a gun at themselves, even a gun with a thousand chambers. The Central European fail safe philosophy, which insisted on prohibition from the point of view of both external and internal safety zones, was at the basis of British thought as well.

The British method of back proving relays, such as approach lock relays, back lock relays etc., double cutting of line circuits, severe restriction on the use of common returns etc., coupled with a relay design that ensured that the top contacts were not made with the relay de-energized, resulted in a condition where prohibition was imposed if any section of the equipment failed.

The Continental practice of checking each portion of the circuit to bring to light any single failure as it first occurred was interesting. The illustration covered a point machine circuit. Would Dr. Oehler say if the same principle was followed in other circuits such as signal control circuits and ordinary line circuits ?

He was not quite sure, really, whether it was always possible to indicate, by any means, the first or even the second failure as it occurred. He thought it was possible that the failure might be there and be dormant. He noticed that in this Continental philosophy fifteen relays were employed for a single set of points. In Great Britain, he thought five or six were used, with three or four conductors to the motor itself; and he wondered whether it was possible that the complexity of circuit design inherently could bring a degree of unreliability. While some greater integrity might be achieved by duplication and complication, the extra points of potential failure might be considered too great a cost to pay for the limited enhanced integrity.

In anticipating the trend towards general acceptance of electronic circuitry and equipment for fail safe purposes, British Rail had employed, progressively, over the last ten years or so, various forms of data transmission equipment for remote control, etc., to connect the main signal box with distant satellite interlockings. These data transmission links had been of non-fail-safe design and the interlocking safety rested with the satellite interlocking.

More recently, one of these data transmission systems (the reed frequency division multiplex system) had been developed and tested to a stage where, it was felt, it had achieved a fail safe standard ; this system was being employed in present design and would enable all interlockings to be concentrated in the main signal box, with reduction in overall cost, since satellite interlockings would not be required. It was felt, too, that it would be better from the maintenance angle since all the interlocking would be concentrated.

Finally, the author referred to the possibility of duplication of components and systems as a means of ensuring that electronic devices and circuits approached the signalling fail safe standard. It would be interesting to know whether the author would, in fact, accept the duplication as a means of achieving a fail safe standard where electronic circuits and components were employed. It might be said that this proposition would reintroduce pure mathematical factors into consideration and it might be felt that a factor of three rather than two might be more appropriate.

Dr. Oehler replied that the circuitry he had shown was just an example. Sometimes the rules were not as strictly kept in other circuits as in this example. Here, they had the most dangerous case, since they had to deal with moving parts in the permanent way. Some of these checks could be left out if one was prepared to take the responsibility for it. This was a question which the chief engineer of a railway had to decide. For example, for the lamp circuit they did not have such minute checks against earthing of a wire, but they always switched the wires of the circuit for the line free indication at both ends. He personally thought this was not quite correct, but if the signal engineer took the responsibility, it was not up to him to make something else.

Duplication of electronic components did not mean that they just had two items of each part in parallel but that two systems worked in parallel; and both at intermediate stages and at the end the result was compared. If the results were not the same, then it could be said that something was wrong. Here again, they did not contemplate that both systems could have a failure at the same time and at the same place. One could do no more than approach absolute safety; they thought this sufficient since it was not possible to attain the ultimate. For example, in remote control they did not use a safety system if they thought of it only as replacing the arm of the man. If the arm of the man was longer it made no difference when he made a mistake, because a mistake he made himself could not possibly produce an unsafe movement. But if the indications the remote control brought back had to be such that the man could base his decisions on them, then they used checks in such a way that each signal was repeated. Only if it was shown to be correct, was the signal sent which gave the line clear indication. This meant that the signal travelled twice to and fro. If anything was wrong they assumed that it could be incorrect only in one direction, because different elements worked in each direction.

With regard to the fourteen relays in the example given, there were in fact many more relays than that in the relay set. The fourteen relays shown were those necessary to demonstrate the principle. Considering the four relays LZR2, 3, and RZR2, 3, these were not required for operation of the points; they simply provided the contacts for the 24 wires of the geographical circuitry; contacts which changed over according to the position of the points. They had nothing to do with the operation itself. These four relays were shown because he wished to demonstrate that they had to be checked. On the other hand, this design of the circuit had been made to meet the requirements of the railways. They asked for such a design in order to attain all the qualities necessary to meet their standards of safety. One of these requirements, for example, was that the points should be trailable. He believed that in many other countries trailing was not possible. Fly shunting was frequent in Switzerland, and the possibility must be considered that points would be trailed. They needed certain relays to indicate this, and they were switched in such a way that trailed points could not be restored without working a counter. This made the circuit a little more complicated than in some other countries.

Mr. A. R. Brown, British Railways, accepted the philosophy that all relays should be proved to move in their required positions, that is to be energized and to be de-energized in accordance with certain requirements; and particularly, that they did not remain in the energized position when they should be de-energized. because that would be a wrong-side failure.

Having accepted that philosophy and then set out how to do it, one had to be careful that, in the determination to prove every possible relay, one did not build a system so complex that numerous right-side failures occurred, and it was realised that when a right-side failure occurred one had lessened the degree of safety of the system, because trains had still to be moved. The human element must come into it and then they must be moved by regulations, so that one had lessened the degree of safety by having a right-side failure.

He quoted the case where it was decided to apply this philosophy to track relays, and track relays were the start of their whole signalling system. If the track relay did not drop, this meant that the train was not indicating its presence in any shape or form. This was a four-track line. It was found relatively easy to do this where there were no connections or complications in the layout. It was possible to prove that the next track relay dropped before the other one would clear. Where one found complications in the layout, the circuits became so complex for all the routes and all the two-way working, that they decided that instead of proving one relay against another, they would monitor each relay by electronic means. This meant comparing the local volts and the track volts against the position of the actual track relay. Now this was expensive. What he wanted to ask Dr. Oehler was, did he do that sort of thing with his track relays?

If so, had he found that there was an increase in right-side failures, because this was what they had found.

Certainly they had found that where the Civil Engineer—the permanent way man—was working in areas where track relays were proved down, the right-side failures had gone up, because he had only to drop a track, by putting a spanner across an insulated joint, or dropping a bolt or something across the rails, for the track to drop and it would not pick up again. Previously this might just have flashed the signal and cleared it again and trains would have run normally. Now one had a right-side failure, and they had checked this by putting pins in a layout diagram and the number of right-side failures had increased considerably, particularly when the permanent way people were doing work. This, he contended, had lowered the degree of safety because in each case of a right-side failure, the regulations had to be put in to move the train. Had Dr. Oehler done this, and had he found an increase in right-side failures ?

Dr. Oehler replied that he found exactly the same thing As a result of proving track relays and, as he had said, proving them with these "block conditions," a failure caused by permanent way men might just prevent a signal from clearing when it could clear. He told a story of a sentry in wartime who had passed the time by trying to walk along the rails in his hobnailed boots. The boots had connected the rails at a joint and caused a right-side failure which had been quite difficult to trace. Their experience was that they had to make careful checks after men had been working on the permanent way.

Mr. Heystek, Netherlands Railways, recalled that Dr. Oehler had mentioned a case of silver-carbon contacts being welded. This was a very important point and he would like to make some remarks on the matter, based not only on the practical experience by the Netherlands Railways during many years of using silver-carbon contacts, but also on the results of the test programme evolved by Committee A31 (safety relays) of O.R.E. (This test programme was put into practice by the Batelle Memorial Institute in Frankfurt - Main). Both practical experience and laboratory experiments showed that there was a fundamental difference between one silver-carbon contact type and another, in particular from the point of view of welding. This difference was a direct consequence of the manufacturing process of the s.c. contacts.

(1) In the oldest process silver powder was mixed as homogeneously as possible with carbon powder, then pressed and sintered. With 5% carbon the s.c. contact was mechanically strong but it still had a certain risk of welding, although much smaller than in the case of silver-silver contacts. With 10% carbon the risk of welding was very small but not zero, and the contact still had reasonable mechanical properties. With 15% carbon the contact would not weld, but its mechanical properties were insufficient.

(2) In a later process, specially developed for the purpose, a solid piece of carbon was impregnated with silver, resulting in a very even and fine distribution of silver in the carbon on a 50/50 basis (50% carbon and 50% silver). These contacts had very good mechanical and electrical properties and the welding risk was zero. This had been proved during long years of practical experience and had been confirmed under extreme conditions in the laboratory. In the Batelle Institute, for instance, this type of contact was not only subjected to the prescribed welding tests, but beyond that to the roughest treatment that could be invented, such as a direct and heavy short circuit of the mains provoked by a contact closure.

The importance of having an absolutely reliable contact was evident. In combination with high-quality relays, these contacts permitted the use of non-proved circuits with their fundamental simplicity and minimum numbers of contacts, wiring, soldering points or connection relays, energy requirements, racks and space (there was no need of air-conditioning in the largest relay room !) Consequently a very high standard of reliability, virtual absence of all maintenance, and easy trouble-shooting (if any was required) were achieved.

Dr. Oehler replied that the picture he showed of silver-carbon contacts welded had come from Rhodesia, and he had written to the Rhodesia Railways for details. They were unable to give the composition of the carbon contact but said there had been no recurrence of the incident, which had occurred in 1953. The relay was the S.G.E. Type BA 312, protected by the BA 040 lightning arrester. Dr. Oehler said that from his examination of the picture he thought the carbon was destroyed entirely and it might be metal-to-metal welding.

Silver-to-carbon contacts had no advantage for fast-acting relays, and the Swiss Federal Railways had decided after tests that for such relays it was preferable to use silver-to-silver contacts. There were many reasons for checking relays other than welding. Contacts might be held up by stray currents and other causes. Welding could be prevented without difficulty, but silver-to-silver was a much more sturdy combination than silver-to-carbon for fast-acting relays, and that was why they had chosen it.

Mr. Steffensen, Danish State Railways, found the question of safe-side failures and their number rather intriguing, and thought there were quite a number of sides to the question. Obviously, in principle, one wanted to have as few failures as possible, at any time, both safe-side and especially wrong-side. But if circuits were made safe and so reliable that one practically never had a failure, what about the poor signalman who did have a safe-side failure ? Did he know what to do in that situation ? Because if he did not, one could have a nasty accident. Of course, he was not recommending that there should be many safe-side failures for the sake of the signalman, but if one had too many failures, then one also had the enginemen getting suspicious of the signalling. They had a certain amount of trouble with that in Denmark ; the enginemen discussed these things amongst themselves. When a man insisted that he had seen a peculiar sequence of signal aspects on a certain signal, and the signal department, having examined the installation very carefully indeed could find nothing whatever wrong, and said : " you must be wrong," it was often still difficult to make the man himself and his colleagues believe it.

Dr. Oehler replied that safe-side failures might not be as numerous as the speaker seemed to think ; the installation should not be such that safe-side failures often occurred and so their train crews had no complaints. It was difficult to ask a driver whether a signal had been clear or not after he had entered a station with the home signal on. Such a case, which was rare, could not be considered as a safe-side failure, because if a signal showed red the train had to stop.

He recalled an incident when two trains entered a station on the same track from opposite directions and stopped a few feet from each other. Nothing serious happened, but there were dangerous possibilities. When questioned, both drivers claimed to have had green. It was then discovered that the day before, the signalman had broken a seal and released a route for a train because the train for which he had already set the route was late. The next day exactly the same thing happened, but this time the train scheduled first had already passed the home signal. Who was at fault ? Because the seal was found broken, the signalman was at fault. An intact seal is proof that the signalman is right, and if the wrong train entered the station the driver would be at fault. Therefore they had to rely on their signalling.

Mr. Koning, Netherlands Railways, said he had read in the *International Railway Journal* that Switzerland would invest some 300 or 400 million francs in marshalling yards and new lines over the next ten years, but only 33 million francs in large signalling installations. He wondered why the latter sum was relatively so small and asked the cost of a resignalling, such as the one at Chur.

Dr. Oehler undertook to reply in writing to this question.

Baron van Heemstra, Netherlands Railways, asked why final permission for a signal to be cleared had to be obtained from the indication of two separate actions. Must these independent actions check the same circumstances, or were they quite unrelated ?

Dr. Oehler explained that in older installations, where they had levers or switches, they used both contacts on the switch and a contact on a relay. This meant that the switch or relay contact alone did not give a clear indication. He thought this arose from a maintenance risk, since a man working in the relay room might, if he was not very careful, give a green by touching a relay if this could act on its own. He thought this was why the Swiss Federal Railways had asked for the feature which Baron van Heemstra had commented upon, and he confirmed that the two relays checked independent functions.

The President then proposed a vote of thanks to Dr. Oehler and coupled with this the sincere gratitude of the Institution to Messrs. de Vos and van Heemstra in particular, and the Netherlands Railways and the Rotterdam Metro authorities for the excellent way in which the whole function had been arranged. He concluded with the hope that this function would be the first of many similar meetings on the Continent.

The official party, consisting of the President, Members of Council present, Past-Presidents and senior members of the Railway and Muncipal authorities had been invited to a dinner by Mr. de Vos of the Netherlands Railways at the Hotel Noord Brabant in Utrecht. After the dinner, Mr. de Vos proposed a toast to the President and the Institution of Railway Signal Engineers; and the President replied proposing the toast of Mr. de Vos, the Netherlands Railways and the Rotterdam Municipal Authority. This concluded the business of the function.

C.F.F. AND S.N.C.F. POINT CONTROL CIRCUITS COMPARED

During the meeting at Utrecht (above), M. Genoux of the French National Railways (S.N.C.F.) raised some questions regarding the number of relays and contacts required for the operation of points in Swiss Federal Railways (C.F.F.) practice. Dr. Oehler supplied a written answer in which the two systems were compared side by side in tabular form as shown below :

CFF			SNCF	
Rst 1[1]		8		
Rst 2		2		
WKR	1		KAg	0
TvKR		7		
RR		4		
RL		4		
RZR1	5		CAg D[2]	6
LZR1	5		CAg G	6
WR	6		Ru	5
JR	1		T[3]	1
10 relays	18×25=43 contacts		5 relays	18 contacts

Notes

1. The relay designations correspond with those in the Key to fig. 1 and Table 1 in the paper.
2. CAgD and G are counted as two relays, corresponding to the combination RZR1 and LZR1.
3. Relay T is counted as a single relay. JR is a P.T.T. type relay with condenser (6 sec.) and one contact. Timing recommences at zero with every command. This relay protects the motor against any persistent overload (e.g., due to obstruction of the points) by releasing relay WR.

Auxiliary Relays

1. Separate detection of trailing requires two more leads than would be necessary for simple detection of the points. For detecting an accidental earth, the normal earthing with respect to the four leads has had to be changed. That is why it is essential for the four leads to carry the detection current.
   Note that switching from lead 1 to lead 2 on receipt of a command, without previous release of the detection is identical to the condition of the points being trailed, and therefore relay Rst 1 has to be used to indicate inception of a command before switching from lead 1 to lead 2 takes place.
2. Since the motor must be continuously subject to the command circuit (independently of the timing operation) and because the motor contacts only show that a movement has been completed (after about 1.5 sec), relay Rst 1 must remain up until the points have finished their stroke. This con-

dition is indicated by relay Rst 2, (the second element of the changeover relay Rst 1—Rst 2).

3. The requirement in Switzerland that trailing of the points must be indicated and stored is met by relay TrKR.
4. The points are moved normal or reverse by an identical command pulse. It is this which makes it necessary to use two auxiliary relays (RL and RR) in conjunction with relays RZR 1 and LZR 1.

The above four requirements show why the five extra auxiliary relays are needed.