

# Technical Meeting of the Institution

held at

*The Institution of Electrical Engineers*

*Wednesday, November 6th, 1968*

The President (MR. B. REYNOLDS) in the Chair

The Minutes of the Technical Meeting held on October 9th, 1968, were read and approved.

The President introduced and welcomed to the meeting Messrs. W. J. R. Norris, A. L. Gower and T. Howard (Students) who were present for the first time since their election to membership.

The President also welcomed members of the Institution of Post Office Electrical Engineers who had been invited to attend the meeting.

Before the Paper on "B.R.B." Miniature Relays" was presented, a recording was played of an introduction by Mr. E. A. Rogers which filled in the background to the subject.

## **Introduction by Mr. E. A. Rogers**

"Mr. President, Gentlemen. First, may I thank you for accepting my introduction to tonight's paper in this unorthodox form. I welcome the idea of making my contribution in the form of an introduction since it enables the historical background to be sketched in—details which are not, perhaps, appropriate to the paper itself.

"The subject of miniaturisation was first aired before this Institution at a Technical Meeting in November 1956. No formal paper was read, but the President, Mr. Kubale, asked me to introduce the subject and, in accordance with the views expressed in the course of the debate which followed, Council decided to set up a Committee to consider what action could be taken by the Institution to generate progress in the techniques. This Committee, under Mr. Kubale's own chairmanship, proposed four sub-committees, of which only that dealing with Relay Miniaturisation effectively got under way, and this evening's paper deals with relays designed to meet the Specifications which it produced.

It is interesting to note the composition of the original sub-committee: Mr. Tyler (the Chairman), Mr. Cardani, Mr. Currey and myself formed the B.R. representation and Mr. Coley (Westinghouse), Mr. Riddle (S.G.E.) and Mr. Crosbie (A.E.I.-G.R.S.) represented industry. Accommodation and secretarial services were provided by British Railways and we were able to call on Mr. Weedon (wearing his British Railways Board hat) as the Committee Secretary. Of the foundation members, four have retired from service, three have held the Presidential chair and I find myself the only survivor. From the start Mr. Candler also joined us, first as deputy for Mr. Riddle and then in his own right until he, in turn, retired and was succeeded by Mr. Leggett. I am delighted that he has joined in the preparation of tonight's paper.

"The Sub-Committee, later promoted to a full Committee of the Institution, reviewed relay requirements from first principles and established such requirements: interchangeability, operating values, number of contacts and their load capacity,

compatibility of materials, timing features, mechanical and electrical life of components. It was not always right first time and, as production got under way, some modifications to the original specifications have been necessary. Some of the decisions were not easily arrived at; it must be remembered that the manufacturers' representatives, while loyally serving the Committee, had to respect their employers' policies and traditions, not to mention their trade secrets.

"But we finished with a comprehensive series of Specifications for relays which, per contact, were one third the size and less than half the cost of the original large plug-in relays. Today there are some 150 000 in use on B.R. alone and, judging from the demands for copies of the Specifications, there is a world-wide interest in the design.

"The process of publication of the

specifications presented a problem in that the Institution was not in a position to finance the printing costs that were involved. It was therefore agreed that on completion, and after approval by Council, each one would be offered to British Railways and, if accepted by them, would be published as a B.R. Specification. Whilst this afforded a practical solution which has worked effectively it has had the result that the products are known universally as 'B.R.B. Miniature Relays', while the Institution, which initiated and devised the design, fails to get the acknowledgment due to it.

"The paper you are about to hear highlights some of the problems that have been met and describes their solutions and few people are as fitted to deal with the subject as our authors tonight".

Mr. L. W. Leggett then read a synopsis of the following Paper.

## **B.R.B. Miniature Relays**

By L. W. LEGGETT\* (Associate) and J. E. CANDLER (Member)

### 1. INTRODUCTION

Relays of one sort or another have been used in vital railway signalling circuits for well over half a century, but looking back at over 300 titles published by this Institution since it began in 1912, reveals only two papers and one booklet headed "Relays". It is therefore appropriate to repeat a little history in order that this paper may present a balanced survey of its subject.

### 2. SURVEY OF RELAYS

#### 2.1. Older Relays (Figs. 1 and 2)

One may ask why such weighty objects as B.R.B. Miniature Relays should be so called, when any electrical man knows of much smaller ones? Actually they are "miniature" (in size but not in perfor-

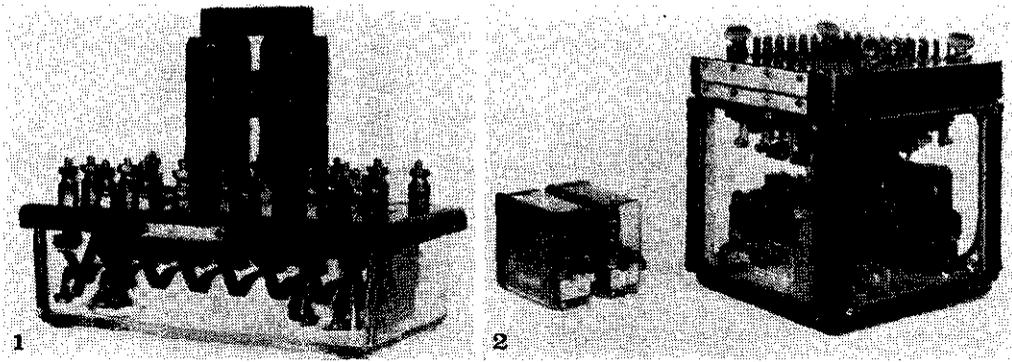
mance) only when compared with their predecessors for vital signalling circuits.

Forty years ago a d.c. line relay with 8 F/B contacts measured  $8\frac{1}{2} \times 10\frac{1}{4} \times 6\frac{3}{8}$  in. and weighed 14 lb., but the B.R. Miniature with 8F 8B independent contacts is only  $\frac{1}{8}$  the volume,  $\frac{1}{8}$  the weight and is much less fragile than the older relay.

Thirty years ago an interlocking relay of a size  $13\frac{1}{2} \times 11 \times 12$  in. had a weight of 65 lb., and was nicknamed "the beam engine". Today we would use two latched relays totalling  $\frac{1}{10}$  the volume and  $\frac{1}{11}$  the weight and with nearly as many contacts.

Line relays for a.c. were even larger than their d.c. counterparts, and can now be replaced by an a.c./d.c. feed unit plus relay of  $\frac{1}{10}$  the volume, and  $\frac{1}{10}$  the weight.

Our younger members should know



Figs. 1 and 2. Older relays and modern miniatures compared

about the veteran relays, but must not despise them. Many thousands are still at work all over the world, numbers have even outlived their purchasers, and heavy relays are still needed where primary batteries are the only source of power. From long experience with older relays the present designs have become possible and reliable.

## 2.2. Intermediate Relays

(Figs 3 to 5)

The P.O. 3000 relay, introduced about 1932, soon attracted signal engineers for indication, timing and train description circuits, but the possible welding of metal contacts barred its use in interlocking or vital circuits. A recent development permits a limited number of non-weld

contacts on this type of relay, and thus a safety version has been produced. Its consumption of 3 watts or more, however, makes its use with continuous primary battery supplies uneconomic, so small

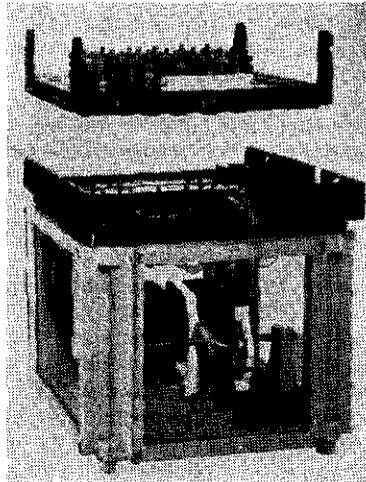


Fig. 4. Shelf relay with removable top

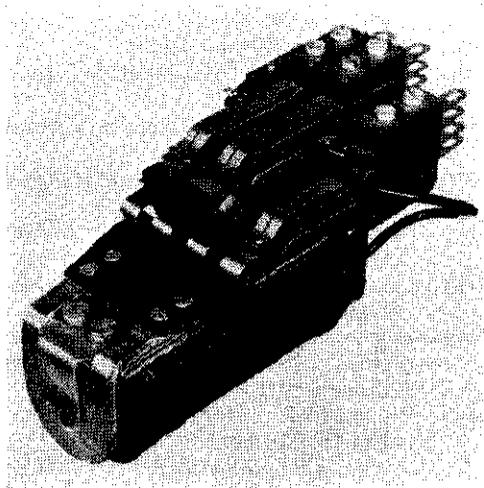


Fig. 3. C.T.C. relay

signalling relays could not be widely adopted until power supply lines spread almost everywhere.

C.T.C. relays similar to P.O. 3000 but larger, more robust and using less power per coil, were introduced extensively in the 1930s for train describer and centralised traffic control circuits, although P.O. relays with twin platinum contacts gave very good results in the same kind of service. A number of other auxiliary or "secondary" relays were also developed.

In the same decade, the large number of signalling relays being installed made it imperative to avoid wrong connections

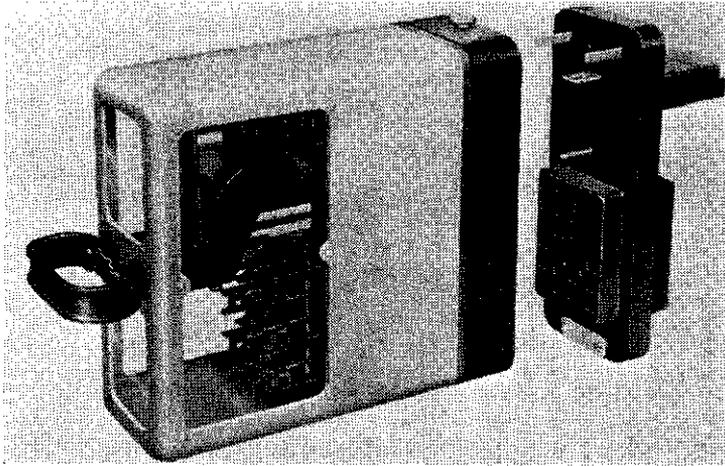


Fig. 5. Standard plug-in relay

being made when replacing a relay, and London Transport pioneered shelf relays with removable tops giving "plug-on" connections, so enabling relays to be changed for servicing in less time, with less risk of error.

About this time, also, "jack-in" bases for telephone relays appeared, and plug-in relays for signalling were introduced in America. The latter, although smaller than shelf relays, could still operate from primary batteries.

Such plug-in relays were smaller, cheaper and as safe as shelf relays with removable tops, so in the ten years after 1945 a large range of d.c. and a.c. plug-in relays was developed in Britain and widely used.

The advent of secure magnetic latching, and advances in rectifying devices, meanwhile made it possible to use d.c. relays in nearly all circuits, so even smaller plug-in signalling relays appeared and were named "Miniature Relays". This stage of the art is very well and fully covered in a paper "Modern Designs of Signalling Relays" by J. P. Coley (I.R.S.E. *Proceedings* 1960) which together with its discussion, should be again studied as covering the earlier chapters of the present subject.

### 2.3. Present Relays

In December, 1960, only one I.R.S.E. draft specification existed, for Single and Double Wound D.C. Neutral Relays; this has become B.R. 930, the first of a series. Since then the I.R.S.E. Relay

Miniaturisation Committee has compiled eighteen more miniature relay Specifications and the present "score" is:—

- 930—D.C. Neutral Line Relay.
- 931—A.C. Immune D.C. Neutral Line Relay.
- 932—A.C. Immune D.C. Biased Neutral Line Relay.
- 933—A.C. Immune D.C. Slow Pick-up Neutral Line Relay.
- 934—A.C. Immune D.C. Slow Release Neutral Line Relay.
- 935—D.C. Magnetically Latched Neutral Line Relay.
- 936—D.C. Polarised Magnetic Stick Line Relay.
- 937—D.C. Neutral Thermal Time Element Relay.
- 938—D.C. Neutral Track Relay.
- 939—A.C. Immune D.C. Neutral Track Relay.
- 940—Provisional. D.C. Single Wound Lamp Proving Relay.
- 941—Provisional. A.C. Lamp Proving Relay.
- 942—Draft A.C. Lamp Proving Relay, for use with Junction Indicators.
- 943—Provisional. A.C. Immune, D.C. Biased Contactor Relay.
- 949—Provisional. D.C. Non-Safety Time Delay Relay Unit, for use in Point Control Circuits.
- 960—Provisional. Twin D.C. Neutral Line Relay Unit.
- 961—Provisional. Twin A.C. Immune D.C. Biased Neutral Line Relay Unit.

962—Provisional. Relay Unit, incorporating a D.C. Neutral Thermal Time Element Relay and an Independent D.C. Neutral Line Relay.

963—Provisional. Twin D.C. Slow-Acting Neutral Line Relay Unit.

In appraising this work it must be remembered that every new relay had to be designed, made and tested before any Specification could be drawn up, that differences between the various manufacturers' designs had to be resolved, and approval obtained for the draft from many signal engineers before publication as a B.R. Specification.

So far about 170 pin codes have been allocated for miniature relays by the British Railways Board. With rationalisation and a greater understanding of which relays are really required, the actual number of pin codes in use in the future should decrease considerably. At first one might think that, with development, more and more types of relay would become available, but in fact certain relays have been integrated. An example is the disappearance of relays to B.R. 935 ref. L by the logical extension of B.R. 936 ref. PS to include a 12N4R relay, achieved by improved magnetic designs.

This survey is becoming almost a paper in itself; it is time we looked at miniature relays in more detail, and it is natural for your authors to do so from the standpoint of design and manufacture.

### 3. DESIGN PROBLEMS

#### 3.1. Planning

In these times when, before production of even a simple relay can begin, many tens of thousands of pounds must be spent on tooling and factory layout, the most daunting question for a design department is not "How shall we make it" but "What ought we to make to satisfy our customers?"

Generally, two or three years elapse between the first design work and the first commercial output. Market research helps but is based on current and past facts, while both technology and market conditions can change quite materially in three years. So a design chief longs for a magic crystal ball, but he can only use his experience, training and intuition. The last is important, because design, however technical, is an art, not an exact science. A good design can be recognised but who

can define it?

Specifications B.R. 930 *et seq.* define what is required and many dimensions; this may eliminate the worst problem, but there are plenty more, including perhaps work on the I.R.S.E. Relay Committee! A few are described below.

#### 3.2. Chemical

Our introduction showed that modern relays are much smaller than older ones, and have less enclosed air space per contact or coil. It follows that corrosion or other chemical actions within the relay are more concentrated.

But there is also now a temperature rise in the coil of perhaps 50°C, and rate of chemical action about doubles for every 10°C rise so such a relay might corrode in one thirty-second the time warm as it would cold! To avoid this snowball effect needs great alertness and chemical knowledge, but with new developments unexpected reactions can occur and in fact can only be completely ruled out by unaccelerated life tests on site for which neither time nor facilities exist.

One well-known example is vapour from phenolic resins causing drastic corrosion on cadmium plate; a less known one is fumes from incompletely-baked varnish attacking copper or zinc plating, or contaminating silver contacts.

The demand for non-flammable materials led to cellulose acetate being used for clear transparent covers—good enough in the dry but later found to give off acetic acid fumes and to collapse mechanically in service in damp railway conditions.

An expensive change was, therefore, made to polycarbonate material, but with this, experience showed up internal moulding stresses which caused crazing unless the component was "annealed" after moulding. One lives and learns to succeed!

Metals in contact which have widely different electro-chemical voltages will mutually corrode in damp situations, hence B.R. 930, Para. 7.5 stipulates limits for such potentials.

#### 3.3. Magnetic Materials (Fig. 6)

At first thought the chief thing about a relay is that it shall operate, but for a vital signal relay surely it is more important that it shall release when required, so the material used for its magnetic

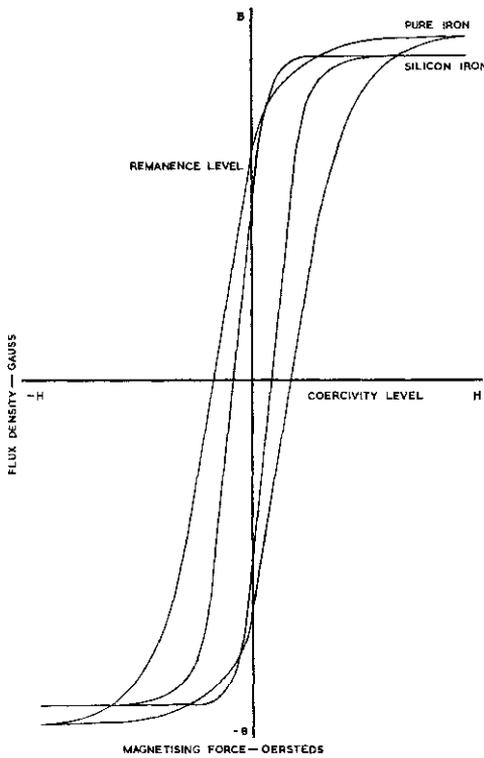


Fig. 6. B/H curves for pure and silicon iron

circuit should have low remanence. If it has high permeability at high flux densities as well, the electromagnet can be smaller, but not much, because it must have a given total flux across the air gap to drive the contacts, and the permeability of air remains unhelpfully at unity.

Some nickel irons have enormously high permeabilities, but at such low densities of flux that they are not useful for electromagnets.

Pure charcoal or electrolytic iron has quite high permeability, but the residual or remanent flux from high densities is also high, and what is worse, as the iron ages, it loses in permeability but increases in remanence. It also is liable to serious differences in magnetic quality between one batch and another.

Silicon irons do not age, they have good permeability, low remanence and great consistency from batch to batch, provided that they are selected, formed and annealed with proper care. The proper

alloy to use is determined by manufacturing facilities, and by detailed calculations for magnet cross-sections based on the armature position—contact force characteristic of the relay.

So, before designing the electromagnet, it is essential to design the contact equipment in full detail, allowing an estimated space and form for the magnet.

### 3.4. Contacts (Figs. 7 and 8)

B.R. 930 stipulates in para. 14.7 that no front contact shall close with a back contact welded, and gives contact positions in Appendix C. So far no maker of the miniature relays has satisfied all these requirements except by using "non-fusible" back contacts, because if metal-to-metal back contacts were used, the contact driving parts would need to be so rigid as to be impracticable.

Silver-carbon is the "non-fusible" contact material most used, and although it is now better than 30 years ago, it is still mechanically weak and greedy to absorb and retain contaminants, so giving rise to more contact faults than would occur with metal-to-metal contacts, but even the protagonists of the latter recognise their greater liability to weld.

If a carbon contact tip contains impurities in the form of water-soluble mineral salts, these will leach out to the contact face in damp conditions and on drying out later can cause very high contact resistance to develop. Such soluble impurities are, therefore, kept below 0.1% by weight. Carbon is a friable material, and any powder debris left from contact abrasion during cleaning, must be completely removed by suitable wiping or again contact resistance increases.

Contact wear in service is a function of the energy dissipated at make and break, when bouncing and low contact pressure periods are equally detrimental; and of the numbers of makes and breaks. Heat energy varies as the square of the current, and is increased by arcing where a voltage surge of more than about 35 V. occurs across the contact opening—hence the choice of 50 V. for telephone circuits as an optimum between high currents and high voltages.

Slight sparking sputters away the contact debris and keeps contact resistance low in service, hence a low-current,

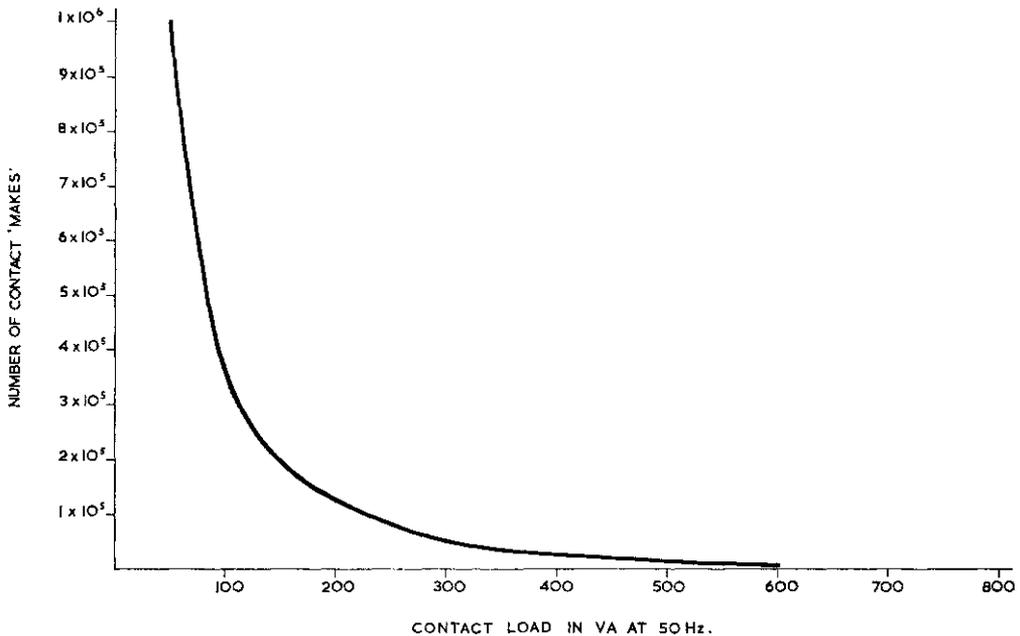


Fig. 7. Typical life graph for silver to silver-carbon contact with lamp load

low-voltage circuit encourages high resistance on a carbon contact; in such a case metal-to-metal contacts would be more reliable if the welding risk is checked.

The common load most destructive to a carbon contact is a gas-filled lamp, because its really cold filament may take a starting surge of up to fourteen times the steady value current. So just as the contacts touch with no pressure they can get a heat surge up to 200 times normal; this minor explosion prolongs the bounce time, causing additional makes and breaks to increase the wear.

There is a widely held idea among circuit people that a contact has a rated current, like a cable core. The authors hope the above facts will show this is wrong; it is much more true to rate a contact in volt-ampères as is common for switches and fuses.

Front or back contacts will, when closed, carry 3 A. continuously, or interrupt 25 VA, d.c. (maximum 125 V.) or 50 VA, a.c. (Maximum 250 V.) without undue wear. At higher loadings the life will be reduced accordingly.

Metal contacts are usually of pure silver or sterling silver, which is harder, or silver-capped copper, and are domed to contact against the flat face of the silver-carbon

element. This combination needs at least 21 gm. contact pressure for reliable service, but more is better, up to 45 or 50 gm., at which crushing of the carbon face may begin to occur. As always, some relative wipe and roll of contacting tips helps to scrub them clean.

For the miniature point contactor relay (B.R. provisional), contacts had to be up-rated from 0.2 to 30 A. d.c. at 125 V., and a.c. immunity entailed a rather slow-acting electromagnet which was not conducive to rapid arc-stretching.

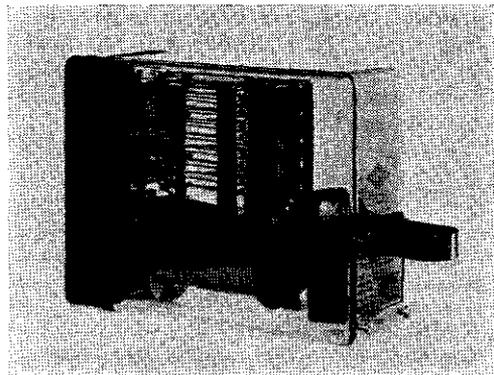


Fig. 8. Point contactor relay

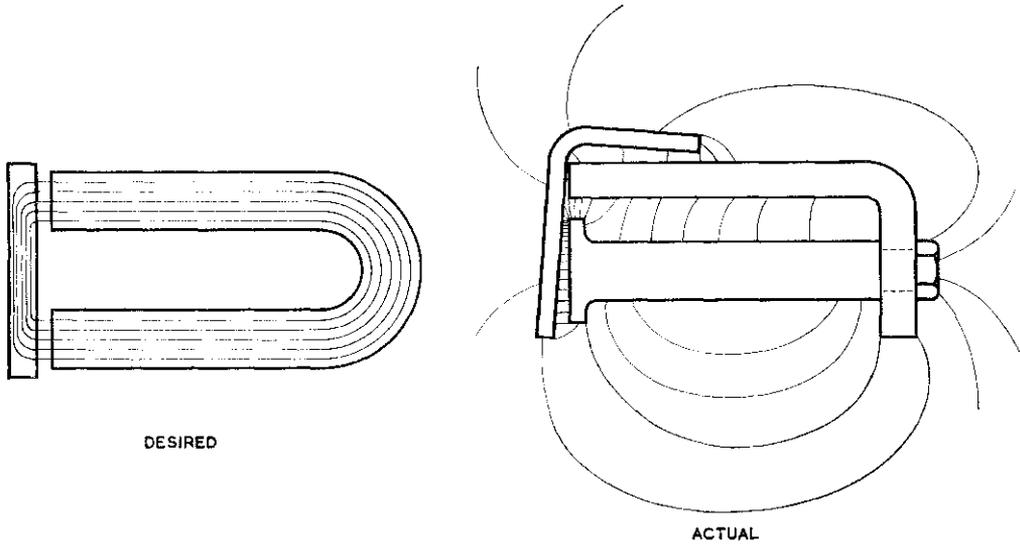


Fig. 9. Relay flux paths

Ultimately, by using modern permanent magnet blow-outs, silver cadmium oxide contact tips and increased return torque and contact pressure, it was found possible, in half the contact space of a B.R. miniature relay, to make and break 100 A. of inductive load at 150 V. d.c. many times in succession without disaster.

This result points to a possible metal-to-metal contact for signalling circuits, and the authors would like to see extensive service trials to gain experience and reveal the snags in the new application. Prototypes have already been made and given life tests.

Miniature relays depend on springs rather than gravity for return torque and contact pressure, so if a consistent ten million operations are to be obtained from all relays made, the contact and return springs must be carefully designed with due regard to fatigue failure, made from closely controlled materials, and finally set to required limits of pressure.

There is little margin for error in the dimensions and characteristics laid down by B.R. Specifications; wrong setting or even over-speed life tests will produce premature mechanical failure in a well designed and made relay.

### 3.5. Electromagnets (Fig. 9)

To design a simple electrical circuit is much easier than to design a magnetic circuit. Consider leakage. The conduc-

tivity of a copper conductor is almost infinite compared with that of its sheathing and usual surrounding medium, but the permeability of iron never exceeds about seven thousand times that of air or other non-magnetic medium, and may be very much less at high (or low) flux densities, so the leakage flux may exceed the useful flux in the air-gap.

It is rather like carrying water in a colander instead of a bucket!

Now consider resistance. That of copper is pretty constant at usual working temperatures, but in a magnet core the reluctance varies wildly at different flux densities, making for tedious calculations.

Having designed the contacts and drive mechanism parts we can get the torque and angular movement of the armature, from which, assuming a centre of force on the pole face, we can arrive at the useful flux needed across the air-gap and the change in gap from de-energised to full energised position.

Using experience, and a little intuition, a tentative armature, yoke, core and pole piece design is drawn, and figures worked out first for useful plus leakage flux, then for ampere-turns needed to drive this flux, at each differing section of the magnetic circuit. Except for a miracle the first result will be wrong in some sections.

The iron cross section is then varied until a workable set of figures is reached

wherein the ampère-turns total is compatible with the coil space and minimum operating voltages. The large majority of total ampère-turns needed are for the air gap in a good relay design, when the armature is likely to pull right through to full contact pressure at minimum operating voltage—a good feature.

To check this, the ampère-turns figures are calculated for each of the four critical armature positions, viz. (i) full back contact pressure, (ii) just-opening back contacts, (iii) just closing front contacts, (iv) full front contact pressure.

If at all these points the ampère-turns needed to first move the armature are less than those given by the coil at minimum operate voltage, the relay will pick right up and squeeze its front contacts.

Given the correct B/H curves for the magnetic material, and enough time and patience, the design work is meticulous but not difficult. Leakage flux can be a nuisance. Armatures can stick or move sideways, and excessive ampère-turns may be needed if too much flux strays from the proper path.

Stray is much increased by high flux densities in the main iron circuit; it varies proportionally to the projected areas of iron facing each other across a space, and inversely as the distance between such faces, hence there are known ways of keeping down stray flux when desirable, but it can never be eliminated. Sometimes it is better to design the pole face and armature details so that flux strays in a harmless direction, for example in a twin relay to avoid one coil holding up the other's armature appreciably.

There seems to be no perfect electro-magnet design; one aims at a good enough compromise. If many designs were needed, a computer might find better compromises than a man has time to calculate.

### 3.6. Permanent Magnets

With so many biased, polarised and magnetically latched relays in the B.R. "catalogue" it would be wrong not to include a paragraph or two on permanent magnets, in which there have been such dramatic developments in the last 30 years, particularly in attaining high coercive forces. In spite of this a major design aim is to avoid weakening or rever-

sal of the magnet by excessive energisation of the relay windings, as may occur if lightning surges reach a line relay for example.

If the magnet is the main flux path it can have a magnetic shunt of low reluctance but must then be much increased in cross-section to carry the shunt flux, and if it is not near the working air gap it must be further increased to carry inevitable leakage flux.

Another way is to plan the iron circuit so that the permanent magnet is out of line with the path of high surge fluxes, when a very much smaller magnet and shunt will suffice for similar duty.

This device takes advantage of the fact that at very high excitation the iron is not greatly more permeable than air, so surge fluxes tend to take the shortest path, particularly if the "out of line" path is of reduced cross section, as is possible.

Anisotropic and similar modern permanent magnets are very sensitive to breaking their magnetic circuit after magnetisation. To take full advantage of such magnets, all workshop and test personnel must be aware of the few precautions necessary to avoid troubles after wrong handling. The designer must instruct accordingly, if only because he introduced them.

### 3.7. Mechanical

It is not a good policy to have contacts which do not weld, iron of low remanence, and safe permanent magnets, then a relay movement which can jam a front contact closed mechanically. So the springs which force the relay down are either in multiple or worked at a low stress to avoid failure. All screws are locked, and all rivets duplicated or very large for their load. Armature pivoting and drive to contacts are arranged so that the risk of a loose part holding up a relay is very remote indeed.

Materials for non-metallic parts are selected for mechanical stability in storage and working conditions in addition to their insulating or other properties. Then a thorough system of inspection, shop and test supervision is necessary to ensure that a good design is made into a good product. It is amazing how well-intending but ill-informed "helpers" can step in

and do unseen damage only revealed much later in service. The users also need advice to get the best out of a new product.

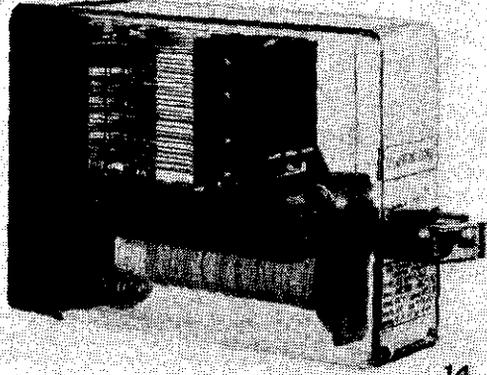
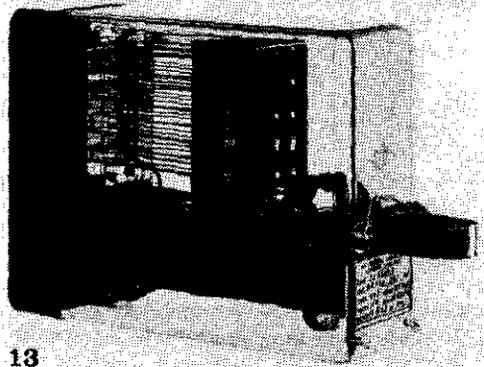
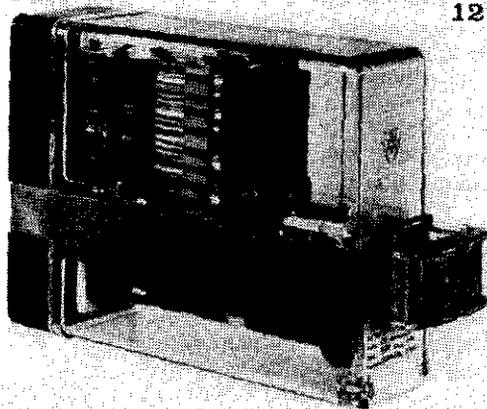
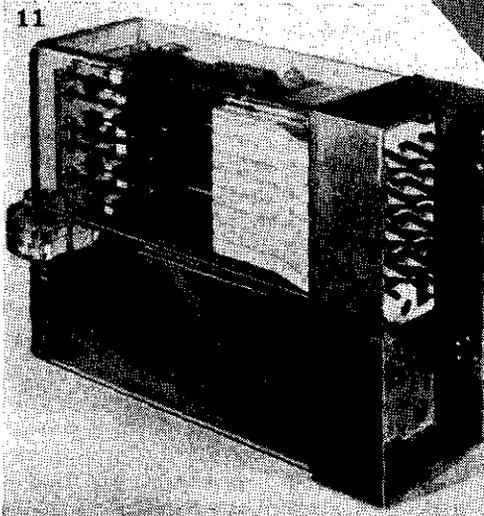
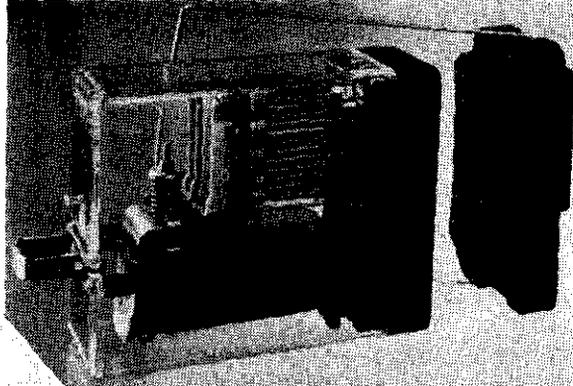
This is *not to claim* that mistakes never occur, or that abnormally rough treatment will not cripple a relay, for nobody and nothing can be perfect, but we must, and do, learn from our misfortunes.

### 4. MANUFACTURE

#### 4.1. General

There have been, and always will be, a number of individual approaches to the method of manufacture. In order to prevent conflicts between specification writers, designers and production engineers, co-operative discussions can be

Fig. 10. W.B.930  
Fig. 11. G.R.S. 930  
Fig. 12. Tyers 930  
Fig. 13. S.G.E. 930  
Fig. 14. A.G.S. 930



employed, but there seems to be no doubt that a technical dictator with a democratic view achieves the greatest harmony.

B.R. Specifications 930 *et seq.* are not complete in themselves; thus the manufacturers of the relays are permitted to use and build in their own techniques. This is discussed further under the heading of type approval and testing.

In this paper only the manufacturing methods of one supplier are described, but Figs. 10, 11, 12, 13 and 14 show five different end products all meeting B.R. 930. It will be noted that Fig. 11 shows great contrast in thinking to the other four.

#### 4.2. Developments

During the past few years it has become essential to amend some of the original ideas for the miniature relays because of field experience. Let us look, for example, at the history of the frame of one B.R. 930 relay, such as shown in Fig. 13. In the original relay an investment casting was used. This technique allegedly offered all the answers to production problems, where machine accuracy was required with complex forms. Because of the reject rate, owing to internal cavitation and the necessity for some machining, all the so-called advantages were lost.

With the problems now encountered, an immediate alternative method for the manufacture of the frame was sought. This was achieved by using a forged frame which did not require a major re-design, nor interruption of production. In order to improve the production techniques still further, a re-design was put in hand which culminated in a bent iron frame made from bar material as shown in Fig. 15.

Although the bent iron frame relay is a very attractive proposition, it cannot be used for all types of relay. Where the relay has a more sophisticated magnetic circuit, such as track relays, lamp proving relays and slow-to-function relays, the forged frame still prevails in the present range.

Means for cost reduction or price stabilisation have also been introduced, as well as improvements to increase the reliability factor, and reduce the reject rate. One has to remember that the number of rejects or service failures must be looked at in relation to the manufactured

quantity and number in service. The casualty rate during commissioning and as a result of commissioning can also upset reliability figures dramatically. (One relay was returned to a manufacturer with a contact pair vaporised and the contact springs melted back for approximately  $\frac{3}{4}$  in. The customer reject label said "one contact high resistance"!)

#### 4.3. Tolerances

One of the main essentials for efficient manufacture is the strict control of piece parts; it is not until relays are completed that some early errors are discovered. With the present-day trend of direct operators taking little pride in their work, the more automated a process can be, the better. This does bring the problem of taking longer to get a new product into full production with the required standard of work, as components, etc., are produced on a production spread basis, but tolerances may fall all one way. An example is that a bar dimensioned 4 in. long  $\pm \frac{1}{16}$  in. may always turn out to be 4  $\frac{1}{8}$  in. long  $\pm \frac{1}{8}$  in. in production. This may appear to show on paper that with all tolerances adverse the relays will not assemble correctly, but in practice they fit together perfectly.

#### 4.4. Assembly.

Great care has to be taken with the contacts during assembly. It is essential that the surface of the silver contacts is preserved and that the silver-carbons are not contaminated.

In one form of relay construction, the carbons are received in chemically clean jars, handled by tweezers until spun on to the contact spring, then placed in polythene bags. These springs, together with the silver contact springs (also bagged) are then moulded into banks, placed in specially-constructed carrying containers and passed to the relay assembly line.

When the contact banks reach the line they are given a pre-setting treatment to align the contacts so that in the free state the silvers are always biased away from the front contacts, and towards the backs. The carbons are set to give approximately 35 gm. pressure in finally assembled relays.

The armature in the relay being described has fixed residual and stop pins.

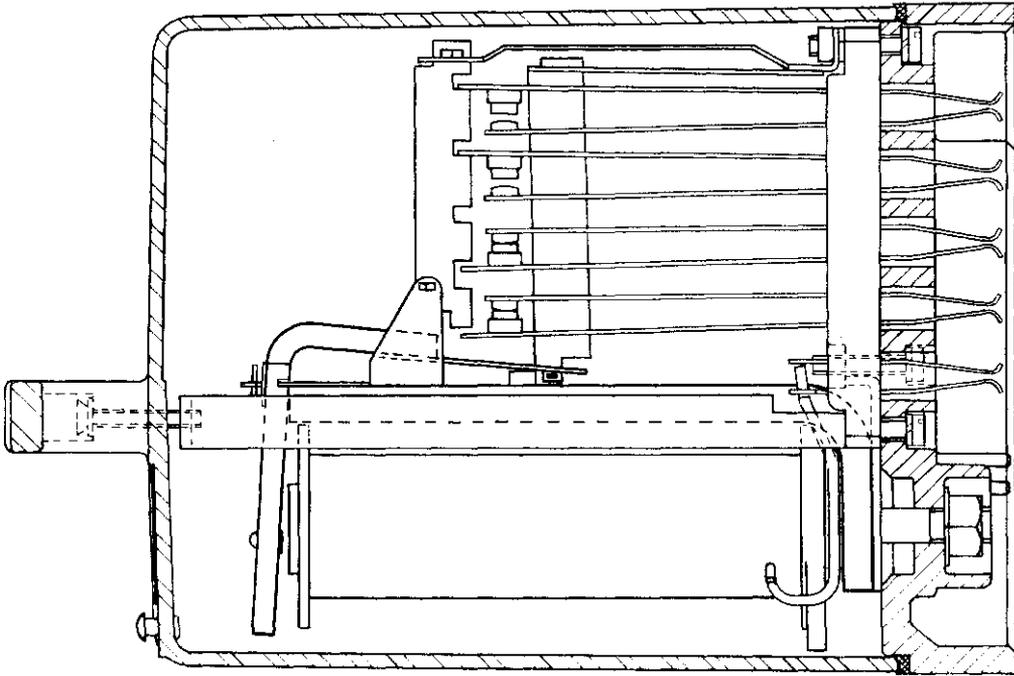


Fig. 15. Bent frame relay

To allow for tolerances in the core and frame, the armature and drive plate are bent to give the correct armature travel.

When the relay has been completely assembled, the contact pressures and alignment are checked. The pressures are taken by conventional methods but the changeover gap is measured on a special jig (Fig. 16).

The lights associated with this jig have the same layout as the contacts of the relay under test, whose silver contacts are commoned and connected via the jig plugboard to the relay frame. The carbons are connected individually *via* the plugboard to the respective lamps; the other sides of the lamps are connected to one pole of a power supply, the other pole being connected to the micrometer adjustment screw which will operate the armature mechanically.

Great care has to be taken to see that the mechanical operation of the armature follows faithfully the electrical operation of the armature. As the screw is wound in, the back lamps light when the screw touches the armature, then the pointer is set to zero. The screw is wound in further, and the pointer reading noted when the

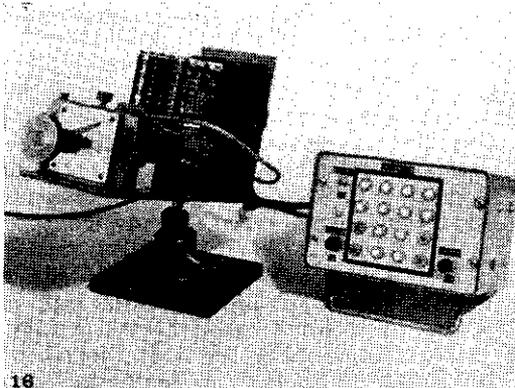
first back light is extinguished, indicating the smallest back lift. When the screw is turned still further, the position is noted when the last back lamp goes out; the back contact alignment has now been established. Continued rotation of the screw gives the change-over gap as the distance between the last back contact lamp going out and the first front contact lamp coming on. The front contact alignment is determined by the distance indicated by the pointer between the first and the last front contact lamp lighting. The front contact lift is measured between the positions of the pointer when the last front contact has made and when no further travel is possible due to the residual pin touching the pole face on the core.

Although this process may seem very complex, an operator soon becomes skilled at the art.

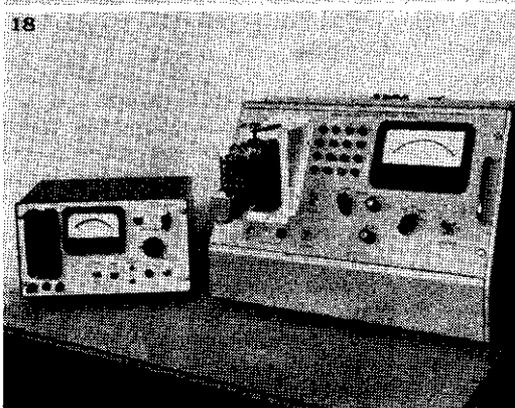
#### 4.5. Testing and Inspection (Figs. 17 to 19)

Before miniature relays are sealed, they are tested and inspected by personnel independent of the production line.

The first test repeats the checks on contact pressure, lifts and changeover



16



18

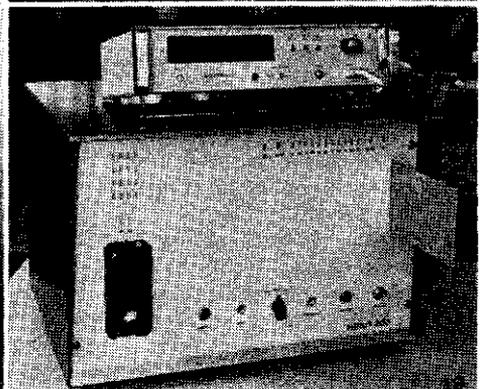
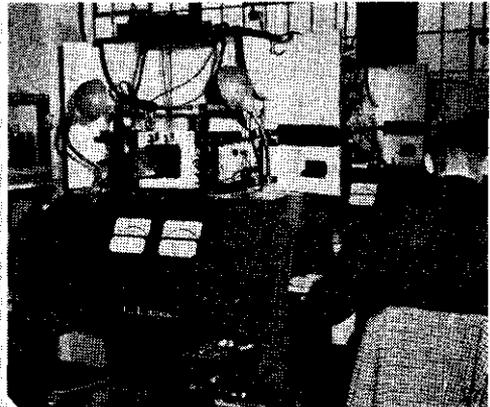


Fig. 16. Lights movement jig  
Fig. 18. Compromise stand.

Fig. 17. Conventional stand  
Fig. 19. Automatic stand

gap. These are followed by a 500 V. change-over test, which applies 500 V.d.c. between all the back contacts wired in parallel, in series with all the front contacts in parallel, the relay being operated 10 times at rated voltage. A current detector which will respond to a pulse of not less than 250 microseconds is provided to indicate a faulty relay with insufficient change-over gap.

After physical examination the relay is checked on either a conventional stand, an automatic electrical tester or a compromise.

A metal card is inserted into the automatic test gear, bearing the description of the relay under test. When the relay is inserted, the machine checks the pin code straight away and gives a "go" or "no-go" indication. If a "go" indication is received, then the coil resistance is checked. If this is correct, then the operate and release voltages are checked.

Next the contact resistances are checked, with a lamp display indicating which contact is under test and illuminated numerals showing the respective contact resistance. It is up to the operator to determine if a contact resistance is outside specification or not.

At this time in a relay's life, the contact resistance is expected to be between 0.01 and 0.05 ohms with 100 mA d.c. flowing. This allows the contact resistance to rise to an approximate maximum of 0.15 ohms after a reasonable storage period.

The value of the contact resistance then depends upon the number of subsequent operations, the period of time between operations and the load. A contact which is operated with 5 mA or less can become very unstable and have a very high resistance, but after a few operations with at least 15 mA, and 18 V., the contact resistance will invariably drop down to its original level below 0.2 ohms.

The biggest problems with high contact resistance today seem to be with contamination during manufacture, and accidental misuse.

The ubiquitous fluorescent lamp produces very flat lighting, the last sort that is required to allow easy recognition of inclusions in relays. Tungsten lighting is the best for this as shadows are created, and with the highlights also produced foreign matter in relays is easily seen. Many relay inspection areas now have diffused background lighting and direct lighting available at each inspection position.

The last check on the relay before being sealed is the flash test. It is then sealed and ready for the customer.

#### 4.6. Type Approval

Type approval is becoming a very great problem for manufacturers. The big question is—who type approves a relay, and how many customers will accept the type approval of others? Some customers have their own particular requirements, methods of type approval and ways of interpreting the specification. Other customers are prepared to accept that, with progress, certain traditional exclusive requirements may be abandoned. It becomes a nightmare when the specifications are used, for and against the manufacturer, as chosen to meet the customer's ideas.

When offering equipment for type approval, should it be typical of production, a production item that has been carefully chosen and adjusted, or a prototype? No manufacturer can afford to initiate equipment and submit typical production samples for approval, as it will then very often be too late to stop production, but this seems to be the procedure according to some customers' thinking. Complete co-operation seems to be the answer, but the manufacturers can only reasonably satisfy one official customer's representative body, which draws up the specifications, type approves, and sees that the ultimate field use is as intended.

#### 4.7. Servicing

The requirement of servicing is not specified for miniature relays. The relays are in general required to have a rated life, and a fatigue life of one order

higher. This means that if a relay is serviced, then its rated life is not extended beyond the original design limit.

Great care must be taken during servicing to use the correct manufacturing procedures, otherwise the rated life of the relay may be reduced. Thus a servicing organisation similar to the original manufacturer's is necessary. One of the biggest dangers to the life of a relay can be "just a run over the contacts and a quick clean". Untold damage can be done, as occurred recently when a workshop cleaned a relay with an active cleaner, to remove an inert substance which could have been classed as technically unsightly.

#### 4.8. Application Environment

Miniature relays are being used today in ways not originally foreseen. This should not be taken as a condemnation of the pioneers, but as a compliment because the use has spread so far.

The big interlockings have provided problems with voltage drop and power dissipation. The nominal busbar voltage of 50 V. can vary on average  $\pm 6\%$ ; this means a minimum of 47 V. The relay specifications call for a maximum operate voltage of 40 V. at 20°C. With the larger number of relays, the ambient temperature is higher than in the past, so only about 3 V. drop in the circuitry is permissible. On average each contact in an interlocking room has a circuit resistance of just less than 1 ohm. This includes wire connectors, contacts at 0.2 ohms, etc. The theoretical maximum number of series contacts permitted, therefore, is about 50, but in practice 100 seems to be the actual limit.

If the nominal busbar voltage is raised beyond 53 V., then further problems are introduced with the relays, mainly due to the timing characteristics. From a designer's point of view, if the nominal busbar voltage is raised, then the nominal voltage of the relay should be raised accordingly, and thus the circle will have been completed with no advantage, but with the disadvantage of higher contact voltage being achieved together with a smaller current, again detrimental to the stable operation of silver-silver carbon contacts.

The power dissipation of a miniature relay can vary greatly. The maximum

coil wattage normally permitted is 3W. for a single and 6W. for a twin relay unit. The contacts are permitted to carry 3 A. each, and have a maximum resistance of 0.2 ohms each. If there are 12 front contacts, each fully loaded, then the total power dissipated by a twin relay unit is possibly:—

$$\begin{aligned} 6 + 12 \times 3 \times 3 \times 0.2 &= P. \text{ (watts)} \\ 6 + 21.6 &= 27.6 \text{ watts!} \end{aligned}$$

This is reduced to 24.6 watts for a single relay.

It would seem practical to assume that each relay can safely dissipate 7 watts on average; therefore, a typical relay rack with 8 rows of 20 relays will dissipate 1.12 kW. Again rounding the figures off, each 5 ft. bay could be calculated on the basis of 1 kW. Unless the rack is properly constructed, the ambient temperature difference between the top and bottom of a relay rack can be surprisingly large.

Thermal relays are the first to suffer from high ambient temperatures, and especially as a 4:1 timing range is required in B.R. 937. It is more usual not to exceed 3:1 in general industry and the P.O. 3000 type relays usually only have a 2:1 range. (One region of B.R. has replaced the thermal relays with impulse counters).

## 5. CONCLUSION

The authors have tried to pass on to members some of their specialised know-

ledge of British miniature relays and hope the paper has not proved dull.

Past and present have been scanned; what of the future? One item not mentioned in the paper may never be fully resolved, and that is the controversial point as to whether the miniature relays should be mounted with the contact mating surfaces vertical instead of horizontal.

Efforts are afoot to abolish the moving contact; shall we ever see multi-channel transistors as robust electrically as relays? Shall we see black boxes containing photocells energised by a common lamp?

Will reliable automatic driving abolish signalling? We wonder, and wish we could return in 50 years' time or more to see the answers, which are bound to come.

## 6. ACKNOWLEDGMENTS

We would like to thank AEI-General Signal Ltd., for permission to present this paper, and for the help received from our colleagues in the drawing-office and test room. Some of the photographs and slides have been kindly supplied by the Westinghouse Brake and Signal Co. Ltd. The reproduction of Fig. 12 is by the courtesy of Messrs. Tyer and Co. Ltd.

Our thanks are also due to the British Railways Board for assistance with some of the other illustrations.

## DISCUSSION

**Mr. A. C. Pearch**, in opening the discussion, thanked Mr. Leggett and Mr. Candler for their very informative paper and summary presented at a most opportune time. Eight years had elapsed since a paper on this extremely important subject was given to this Institution by Mr. Coley, entitled "Modern Designs of Signalling Relays". In his paper Mr. Coley spoke about the salient features of the then new I.R.S.E. specification for miniature relays and went on to describe and illustrate the first production relays which had been designed and manufactured to this new specification.

The paper heard tonight showed the further progress which had been made in the design and manufacture of this range of relays since that date. One of the most important advantages resulting from these

developments was the lower cost of the B.R.B. miniature relay compared with previous designs; this particular point had already been brought out by Mr. Rogers in his introduction.

In 1948 shelf type line relays with eight front/back contacts cost in the region of £15. In 1960 the large plug-in versions with 12 independent contacts sold for between £25 and £30. Now in 1968 when the pound had only 25% of its former purchasing power, one found that the modern miniature relay with 16 independent contacts was being sold to customers in the range of £12 to £16 depending on type, and complete with plugboard. This was a worthwhile achievement in these days of rising material and labour costs.

In Mr. Coley's paper the question of carbon versus metal to metal contacts was

raised, and eight years later it was right to ask if the correct decisions were made at that time, now that there were many hundreds of thousands of these B.R.B. relays in service throughout the world. Apart from initial troubles such as plating, cover distortion, and contact contamination, he would contend that the vast majority of these relays had given good service and would continue to do so for many years.

The experience gained over the past eight years would ensure that the B.R.B. relay would give as good, and perhaps a better performance, than its Continental counterpart, especially under the extreme climatic conditions which these relays had to meet in outside location cupboards. If this statement was accepted, then the much simpler circuitry which resulted from the use of non-weldable contacts was surely the right course. Tighter control over manufacturing processes would ensure a high-quality product for the future, providing manufacturing costs were not subjected to pressures from intensive and cut-throat competition, which could result in changes to existing design and engineering standards—not for technical but for purely financial reasons. It was also very essential to have continuity of work on this type of product to avoid loss of know-how and expertise in manufacturing. It took many months of training for experts to make sure these relays were of the highest standard.

In Section 4:6 the authors drew attention to the problems of type approval. Manufacturers had certainly a difficult task in attempting to satisfy all their various customers in this respect. So far as British Railways were concerned, this should be carried out by one authority for all railway signalling equipment—permitting a larger production of standard items, reducing manufacturing costs and assisting greatly in the export drive.

Mr. Leggett and Mr. Candler asked what of the future? Apart from an increasing use of electronic techniques in the non-vital sections of interlockings, it was difficult to see how electronic equivalents to the present safety type relay with its ability to control up to 16 independent circuits, each electrically and mechanically isolated, could compete in cost. Electro-mechanical relays could be introduced directly into existing signalling circuits

without any additional interface. Electronic equipments would need to be looked at most carefully if they were to be judged against the very exacting requirements of existing signalling relays and circuits.

No doubt pressures would be brought to bear on signal engineers to modify the present standards so that the more fashionable electronic devices could be used. If ever one arrived at such a situation, then these modified standards should also be applied to their signalling relays, making these products even more competitive. Signal engineers had always been told about the high cost of signalling. Was it possible to reduce the cost of relays by designing for limited life, for being serviced at regular intervals, and then throwing the article away at the end of its life cycle? Did one have to be able to inspect visually each contact? Could the relay be made cheaper, and/or work more efficiently, by having a contact drive plate in front of the contacts, allowing more precise control over contact location and the use of fully-automated methods of contact spring adjustment and setting? Would they get better reliability from their contacts if the mating surfaces were mounted vertically as suggested by the authors? He was sure a lot of research and investigation went into the Post Office decision to mount the 3000 relay in this way. All these things contributed to lower capital and maintenance costs, and should be thoroughly examined by B.R.B. for the future.

**Mr. Leggett** said he and Mr. Candler agreed with all Mr. Peach had said: "Throw them away when they are finished, don't bother to service them". He thought he was right in saying that the original intention of the I.R.S.E. Miniaturisation Committee was for these relays not to be designed for servicing, but to be thrown away when they had completed their rated life without trouble.

Front-drive of contacts would certainly help; it was an embarrassment having to provide a front view of contacts—how necessary was it? In most relay rooms it was quite difficult to see relay contacts even with a portable lamp, because of interference by reflections or shadows. Surely the usual thing was to remove the relay if it was giving trouble, examine it, then either replace it, or substitute another

and return it to the manufacturer.

**Mr. J. E. Candler** commented that Mr. Pearch evidently wanted cheaper contacts. He was not at the early meetings of the Committee, so did not know how very nearly they did indeed get metal contacts. Had it not been for some welding experiments carried out by Mr. Cardani on the Western Region, he thought they might have had metal contacts. In his opinion they were all right if one could be certain that the prospective short circuit current was limited to less than the tack welding value of the contacts.

**Mr. B. H. Grose** said that as a comparatively new boy to the I.R.S.E. Relay Miniaturisation Committee (he had only served a five year sentence), he was pleased to open for what was sometimes regarded as the opposition by the manufacturers (and he might add not only by the manufacturers) as he had had the pleasure, and, he might say, honour, of enjoying the whole-hearted co-operation of the authors on that committee.

As engineers they were all aware, he was quite sure, of the opposition to co-operation which sometimes existed at high management level, but on the Institution's committee, happily this had crumbled under the pressure of engineering necessity where prestige had no connection with reality. It was an obvious fact that this was the age of big battalions and, because of the increasing complications of technology, small companies could no longer go it alone. This was nothing new; the forced mergers which were now taking place had in fact been a feature of railway history for at least the last hundred years. Even at that time technology was too expensive to be dabbled with by a multitude of small under-capitalised enterprises, and many such endeavours started with high hopes but soon fell into the hands of the well-entrenched companies. Co-operation was therefore better than independence if the latter ended in Carey Street or assimilation by a financial empire the objects of which were inimical to the unfortunate victim of the take-over bid.

This led him to say that anything which would promote the wellbeing of the signalling industry was well worth supporting whole-heartedly; and standardisation was one of those things and of course he was

interested in standardisation, coming as he did from the Board.

This further led him to say that B.R.B. miniature relay specifications, which were small in number at present—and they hoped they would increase—nevertheless were tangible proof that it was to the advantage of all concerned in their use and manufacture to co-operate. He hoped this would extend to other fields with corresponding benefits, as in the prevailing financial climate they could not afford to continue to accept the sophistries of those who argued for standardisation but only on their own terms.

Another thing that these specifications had depended upon was a good human relationship between the persons concerned in their compilation; much more could obviously be achieved when minds were in tune than if all efforts were made independently of one another. Happily, this had been and was still so in their Institution's Relay Committee.

Referring now to the paper, he could see that one of his other hobby-horses was at large in the section devoted to magnetic materials. Here it was stated that it was more important for a relay to release than to operate. While this was incontestable, in fact the margin in his opinion was vanishingly small; in other words reliability was as important as fail-safe. He said this repeatedly to anyone who gave him a chance, or even half a chance, since the idea was commonly held that the signal engineer had fully discharged his responsibility by ensuring that all apparatus was fail-safe. He submitted that this was a naïve view of their task since fail-safe apparatus was not synonymous, and he repeated "not", with fail-safe signalling. This would be so only if no trains ever moved after a fault until the signalling system was in correct functioning order again. They all knew this was not so and therefore it was not good enough to relegate reliability to second place.

As wrong-side failures could not be eliminated from any man-made equipment, it would be ideal if the rate of wrong-side failures was such that they would never occur during the working life of the equipment. If during this life the rate of right-side failures was reduced then regarding the system in total it would become safer. This might seem strange—that eliminating right-side failure increased

safety, but if it was accepted that one could not have fail-safe signalling this conclusion must follow. In other words, the more reliable the equipment was the safer the railway became, and this conclusion must apply with equal force to any system which fell short of the ideal which he gave before. He therefore regarded it as most important that their younger colleagues should be made fully aware that there was more to the safe running of a railway than closed circuit principles.

The details the authors had given on contact life in the paper were extremely valuable. He had never seen this information before, and it filled a gap in the knowledge as to what would happen to a relay if one loaded it more than the designer stated; he also felt that the curves given on contact resistance were extremely valuable.

He must draw attention to the fact that the authors had "jumped the gun" and leapt into the future, so to speak, by disclosing the B.R. specification numbers of the last four specifications. In case anybody wondered why they had not had those specifications regionally, they were quietly allocated, but were not for publication yet.

Mr. Pearch had a swipe at the Board about type tests; it was his (Mr. Grose's) job to organise those type tests. Well, he was poised like a greyhound in the slips waiting for the manufacturers to stop changing their designs. With regard to the edge-on contacts, or vertical contacts as in the Post Office 3000 type relay, when he was over in France recently they told him that the S.N.C.F. had for a long time had vertical contacts, but they were contemplating changing them to horizontal ones, to increase reliability. So he thought the Post Office tossed for it when they made their decision.

He would like to ask the authors how the term "piece parts" came about. He was aware of its venerable nature in the telephone industry, but it seemed to him to be a classic case of redundancy. A piece was a part, and a part was a piece. Whatever the answer was, it showed how they had been in advance of current research in O.K. words for many years.

Lastly the authors said "What of the future"? And they referred in the paper, to the use of transistors and the like in place of relays. Well now, members of

the old school took comfort in their contact openings and heavily-insulated wires and shuddered at the idea of the intermolecular barrier which performed a similar function in a semi-conductor device. It was unthinkable that they could ever exchange the latter for the former, but why not? They relied on the intermolecular faces of a bearing for the safety of their relays! The only difference was that the latter was well proven by experience. He could see no reason why one day semi-conductors should not be taken for granted in just the same way, and take the place of their safety relays.

Mr. Candler replied that he had always been such good friends with Mr. Grose that they could be rude to each other without offence, but he would assume his plea for more reliable signalling was not aimed at relays! Agreed, release was more vital than operation; still those relays were pretty reliable; scores of thousands of them were used on the London Midland Region, but they brought him here on time without any bother that day and on many other occasions.

Piece parts was the term used when he came into the "trade" nearly fifty years ago. The Americans said "components"—inefficiently, he thought, since they used an extra syllable, but on the shop floor people usually said "bits".

He was grateful for Mr. Grose's complimentary remarks and other comments.

Mr. E. J. Harris found it surprising that the paper they had heard was only the third to be read to the Institution on the subject of relays. He felt it would be agreed that this paper, dealing principally with design, manufacture, assembly, inspection and test aspects of the B.R. 930 series relay, was a very informative paper and gave some indication of the considerable research work necessary on signalling apparatus to maintain the record of safety and reliability which had always been the predominant factor in their profession. Having been responsible himself for the design and manufacture of relays, he would endorse the author's remarks as to the problems that a design chief had at the planning stages of a new design, particularly in respect of process technology where attractive new methods were possible, but where very limited practical experi-

ence was available. There was no substitute for a genuine life test, and whilst accelerated life tests were carried out, it was not always possible to design out all the problems that were encountered.

The authors quoted two examples where actual service brought out problems not appreciated during extensive testing in the laboratory. He could assure them that they were not peculiar in this. His own company had found, for example, that the resin used on the coil could, if the incorrect type was selected, cause a crystalline structure to form inside the relay. They carried out laboratory tests on this particular relay, together with accelerated life tests, but it was not until the relays were actually in service that this problem was encountered.

He would also like to associate himself with the authors' remarks with regard to type approval, and also with the comments about this from Mr. Pearch and from Mr. Grose. In order to attain type approval it was necessary to provide a production relay, which involved the supplier in the full manufacture of tooling, and any modifications requested thereafter could be very expensive. It could also be appreciated that the delivery of a type-approval relay could take considerable time and it would be really the first-off production relay. It would seem to him that approval of a new design should be provisionally given after submissions of the drawings and a detailed specification of the relays to the customer, and providing the finished product fulfilled the agreed specification, then it should be acceptable.

Mr. Candler and Mr. Leggett quite rightly stressed in their paper the need for cleanliness during the processing of contact materials. He would like to hear their comments on the provisions made to ensure cleanliness of all components within the relay. Did they use ultrasonic methods for cleaning individual components—was any technique other than visual inspection used as a final check? In his opinion a particle of foreign matter within a relay could be more dangerous than an increase in contact resistance due to contact contamination.

**Mr. Leggett** replied that he and Mr. Candler were pleased to note that they had at least one supporter among their

competitors. One had to have completely clean areas for assembling relays to ensure that there were no inclusions or else one had to spend an awful lot of money on inspection at the end. How clean should a clean room be? He understood that in some semi-conductor factories they'd much rather the operators didn't breathe! He did not think they need go to those sort of limits but he considered it essential that all relay assembly areas should be isolated and kept as clean as possible in order to reduce the inspection problems both to the manufacturer and to a customer's inspectorate as well.

They did not use any ultrasonic method of cleaning; they had tried ultrasonics on one occasion for a particular cleaning requirement, but found that it did not give the results they had hoped and abandoned the idea. They still relied, for their part, on the visual check and a good blow-out with clean air. They opposed good blow-outs with very doubtful air; it was the requirement that each assembly area and test area had a specially clean air supply instead of just the general factory supply.

**Mr. Candler** added that in his opening remarks, Mr. Harris had mentioned that this was only the third I.R.S.E. paper on relays. Actually there had been many other papers mentioning and illustrating relays, but the authors thought it would make an arresting opening to state, truthfully, that there had been only two previous Institution papers with the word "relays" in their titles.

**Mr. E. W. Wager** said he would like to begin by putting the record straight concerning a previous speaker's comments in thinking that London Transport still had in service a relay of ancient design which, he believed, was called the "Brown" polarised relay and used in conjunction with d.c. track circuits. About 15 years ago the last relay of this type was removed and presented to the original manufacturer and he would not be surprised if it now occupied a place of honour in his museum if he had one.

London Transport over the past 40 years had used the a.c. vane type of relay as shown in Figure 4 in the paper. They were comparatively newcomers to the use of the B.R.930 relay but in fact the

opportunity had been taken to equip the whole of the new Victoria Line with this relay in a modified form. The modification mainly concerned the method of wire connection and use in a dual form. They were so far only using two types of this relay: one was a line relay of the low voltage d.c. neutral type operated from a 100 v., 125 Hz supply through a transformer rectifier, and the other was a 50 volt d.c. line relay used as a track relay in connection with the coded track circuit.

Each signalling function operated a pair of B.R. 930 type relays in order that a double cut circuit technique could be employed. The contact of the first relay was inserted in one pole whilst the contact of the second relay was inserted in the other pole of the circuit. Mr. Hadaway in his paper "Fail Safe" dealt with this method at some length and no doubt London Transport would enlarge further on this subject at a later date. He was pleased to be reminded that L.T. had pioneered the relay with the removable plug-on top, and the feature of not disconnecting the wires when changing the relay had been reproduced in the new relays on the Victoria Line. Each terminal connection was made by a screw such that when the screw was removed to detach the relay, the wires remained connected to their respective terminals in a captive base. The authors said relays had to be used, which was disturbing to the 'designer', and he thought there was a certain amount of truth in this. The point he wanted to make was that they were very conscious of the methods of wiring and installation let alone the performance of the relay. Most of the subject matter that night had been on the performance of the relay but he also maintained it was vitally important to ensure there was complete segregation of one circuit from another at the point of termination of the wire to the relay, and he thought they on L.T. had gone a long way to meeting this in their new designs.

He would like to ask what experience there was of failure of the plug-in connection and how it was overcome. It seemed to him one could well test and find one had contact trouble, jack out the relay and plug in another, thinking it was the relay when in fact the point of the plug-in connection could be the cause.

Turning to the description of the various types of relays, he was rather confused here

because he understood the term neutral line relay to mean that the relay would operate whatever way the polarity was connected. He would like the authors' clarification of what was meant by a d.c. biased neutral line relay.

He thought the method of relay adjustment was excellent and provided exactly the information required.

The question of contact resistance had been exercising their minds for some while on L.T. and they had been carrying out tests for the past six months, with the result that they believed they now had a clue to the cure.

A point was made about the fact of metal-to-metal contact, saying that if a limiting resistance could be provided this would overcome the danger of welded contacts. What safeguards would they take to ensure that the resistance itself did not become short circuited?

Lastly, several points had been made about the questions of safety, particularly the possibilities of welded contacts. Bearing in mind the automatic era and the fact that no longer would there be signalmen present to oversee the signalling and perhaps in the future there would no longer be a driver on the train; and further, that the whole installation would be working automatically, should they not then reconsider the continued use of the single cut circuit in favour of the double cut circuit to guard against a relay falsely sticking up?

**Mr. Candler** replied to Mr. Wager's question about experience of any plug-in contact failures. They did get some trouble in the beginning, but it was due to bad alignment of contacts; either both blades went one way, or they hit the end of the fixed blade and stubbed and bent, but, as far as he knew, in the last several years there had been extraordinarily little trouble in that respect.

If one looked at Appendix A of B.R. 930 it would be very difficult to get round the very accurate specification; all the dimensions were there and if one worked to that, apparently one was perfectly all right.

"Biased neutral" was one of those terms that was a bit like "piece part"; it had been in existence for very many years—he thought it started in America. What it was intended to convey was that the

relay operated on one polarity like a neutral relay; i.e., it picked up when energised, released when de-energised, but only operated if the positive pole was on the right terminal. If one reversed the current to the relay it did not pick-up and it was therefore in a sense a neutral relay which was biased to pick-up only with the correct polarity.

Regarding single-cut versus double-cut, he was not a circuit man, but would agree that double-cut was safer although more expensive.

As regards having resistance to prevent welding of contacts, the only safe way in his opinion was to have about  $\frac{1}{2}$  ohm in the supply source and busbars so that one could not get rid of it, and if it was there one would not get welding current. Of course, they had not much experience of this; they were only just starting on metal contacts. He believed that on the Continent they did put limiting resistances in their circuits where they used metal contacts.

**Mr. Leggett** said all he could add was that he was quite unaware of any recent troubles that had been experienced by customers with the contacts on the plugboard when the relays had been plugged in. Since the plugboard moulding had been slightly modified, it had not given any trouble at all, and this had been the case for many years now. The B.R. Specifications had been altered for the plugboard to eliminate some pips that were originally there to give additional tracking distance, but in fact were the cause, he understood, of the contacts going the wrong way and distorting.

With regard to metal-to-metal contact with resistance in the lines, if one took an average circuit of battery, bus-bars, fuses and wiring, it was surprising how quickly a quarter or half an ohm appeared, and providing one made sure of having at least that, one had the protection required for the new metal contacts. Therefore, with the type of material they were using, they could not see that any additional limiting resistors were required. Some Continentals used silver-to-silver contacts. What they had used was a material introduced for the point contactor which was not the conventional silver-to-silver contact.

**Mr. G. D. Miller** had been very

interested indeed to hear of the trial batch of relays going into service with metal-to-metal contacts. He assumed that this trial was being carried out in order to reduce the number of failures due to high contact resistance, and he wondered if the authors could give some indication of the order of improvement which they were expecting to get; what were they looking for? He wondered also, if the authors would agree with him that one of the unfortunate aspects of the B.R.B. 930 design was the inclusion of the coil within the same case as the contacts. There was an arrangement of plug-in relays produced in America, where the coil was outside the case of the contacts. Now in this design, which was inverted compared to the B.R.B. 930 with the coil on the top, the contacts could not be contaminated by vapours from the coil. With the present design, as limited by the specification, he thought it would be very difficult to provide that feature now. He would like to hear the authors' views on this, particularly following on the remarks of Mr. Harris about crystalline growth coming out of the coils.

Finally, it might be interesting to mention a novel approach to the problem of producing a cheap safety relay which had been designed by the Aster Company in Paris and which he was fortunate to see recently. In this they had produced a double relay rather in the style of London Transport, but by using metal-to-metal contacts they had scaled the whole thing down and had got the two mechanisms in one case. By doing this they were able to provide a novel form of latch between the two mechanisms, so that if one stuck for any reason and the second one failed to come into correspondence with it, the mechanism latches left the relay with no contacts made. This was obviously a very safe condition and it constituted quite an interesting way of providing a safe relay with metal-to-metal contacts.

**Mr. Leggett** said with regard to Mr. Miller's comments about contact resistance, their medium-duty relays with the metal-to-metal contacts were introduced not for reliability of the contacts but because of the increased circuit loads that were now required. One was limited to 25VA d.c. and 50 VA a.c. on the standard signalling contact, but there were occasions when one wanted to handle less

current than the point contactor would and therefore this medium-duty contact arrangement was thought about and produced. The trial runs were for lamp loads where, for example, on barriers one had the problem of switching the lamp load, mainly of two 36 watt, 24 volt lamps. The reason for the development was to increase the load capacity of a contact, and had nothing to do with the occasional high resistance of present contacts.

It was very nice to come along with the idea of having a coil outside the miniature relay at this time, just after they had sweated blood to try and pack everything in the case, and had reached the point of eliminating the crystalline growth and various other problems. They would hate to think that somebody was now prepared to say "well, you need not have worried, you can have it outside!" They might have considered it outside, but having got it inside, he did not think they ought to redesign it. The Aster relay just mentioned sounded rather complex, it also sounded like a variation on an old theme. He believed Mr. Candler had recollections of an earlier relay with the same features.

**Mr. Candler** agreed that about 10 or 20 years ago they were making a thing called a G.C. relay which was two d.c. relays inside one box and interlocking one with the other so that if one did not operate the other could not either. It might be something like this Aster one, but evidently the Aster relay was much reduced in size compared with the old plug-in type. He had not seen this Aster relay, so was not in a position to judge what it is like.

**Mr. A. R. Brown** said he thought it was the L.T. representative who raised the question "Had they any trouble with the male and female contact in the plug base?" They did have trouble; they still had trouble; he wouldn't say this was frequent but one found it occurred when there had been alterations on an installation and men had been working in the signal cabin disturbing wiring, perhaps preparing and carrying out alterations in the bases, and invariably a week or two afterwards they got the odd trouble. There were times when, he was sure, in testing a spade was removed to drop the relay: this was likely to be a weakness when that spade was

replaced. If one said had they had trouble? Yes, there was trouble, but not excessive.

Regarding carrying out rules and regulations, on many installations there was no easy means built in to carry out the applications of rule 77 or rule 81 and there were cases when a relay had to be de-energised by removing the spade. Any case where the spade was removed was likely to leave them with fault potential in the future in that relay base. He knew on some installations, and he thought this was the right way to do it, special facilities were built in at the design stage for carrying this out.

With regard to metal-to-metal contacts, somebody said that they were glad they were having some relays that they could now do trials on. He thought he was right in saying that certainly both the Midland Region and his own region had quite a lot of plug-in relays that had metal-to-metal back contacts. He thought these were called the C.B. type. He did not know how they really got into service. There had been questions asked about them but to his knowledge he did not remember any welded contact on those relays.

**Mr. Wager** also raised double cutting. Double cutting made the circuit safer against a false feed, but it did not give any protection whatsoever from a mechanical stick-up of a relay.

The question, too, was raised about putting the coils outside. One could remember the case where the M.O.T. was very concerned about contacts on the relays which could be touched by the technician despite the fact that these had a built-in cover, but the cover could be removed. He did not think that coils outside would be "on".

**Mr. Candler** replied to Mr. Brown that it was very difficult for manufacturers to know what happened to their stuff after it got out into service past the period of one year's maintenance. It was rather heartening to find that they did not get much trouble and that what there was always arose after people had been changing the wiring. It was, of course, easy, he should think, to bend those tags as one pulled them out or pushed them in, and alterations on railways were usually done in a hurry against time.

**Mr. Brown** also mentioned metal-to-

metal contacts on what he called, quite rightly, C.B. relays; none but back contacts ever were fitted metal-to-metal on the C.B. relays, and in this case they were silver-to-silver contacts, they were not this special alloy which had just been introduced.

**Mr. Leggett** enlarged on the silver-to-silver contacts in the C.B. relays; the current was low and the relays were only designed on the assumption that one would never be able to more than tack weld the contacts by the currents which might be in the back contacts. There were also, of course, low voltage circuits—about 12 volts at that time—and therefore it was advisable to have silver-to-silver back contacts. The relays that were going for field trials had only metal-to-metal back contacts at the moment, although they showed a relay with the metal-to-metal front contacts which had been on a life test.

**Mr. D. J. A. Hobbs** recalled that Mr. Wager, in his contribution to the discussion, indicated that on London Transport they had been carrying out investigations into contact resistance over the past few months, and he would like to give a brief outline of these investigations.

They had operated several relays, of the type that Mr. Wager illustrated, continuously on a cycle of  $7\frac{1}{2}$  seconds energised,  $7\frac{1}{2}$  seconds de-energised, and these had exhibited very high contact resistances.

Typical results obtained from a relay after 1,000,000 operations were:—

	Contact Resistances ( $\Omega$ )		
	at 100mA d.c., 24v.		
	Lowest	Mean	Highest

8 Front Contacts:

Graphite+/Silver-	2	10	20
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8 Back Contacts:

Graphite-/Silver+	1	4	10
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A relay with standard silver and graphite contacts, but without dust cover, was operated outside in the open air and the correlation of the extremely erratic results with the atmospheric humidity eventually became apparent. That was to say, periods of high humidity quickly reduced contact resistances to low values, and long dry periods allowed the resistances to rise again to high values similar to those tabulated.

A relay operated with its contacts in an

atmosphere saturated with water vapour had given very low contact resistances over several hundred thousand operations. It became apparent that the problem of high contact resistance with graphite contacts might be related to the phenomenon of carbon brushes known as the High Altitude Effect. The dramatic effects of the lack of water vapour on the wear and lubrication of carbon and graphite brushes had been the subject of investigation for many years. During the Second World War it was found that brushes which operated satisfactorily for long periods at sea level would wear away within minutes in the very dry conditions obtaining at high altitudes. Subsequently it was found that impregnating carbon and graphite brushes with metallic halides was effective in countering high rates of wear in dry air, and later, additions of lamellar solids such as molybdenum disulphide were successfully used. They therefore had concluded that high contact resistances might be due to wear of graphite contacts, due in turn to inadequate lubrication; and that the problem might be overcome by the provision of a suitable lubricant.

A proprietary contact lubricant was applied to the contacts of a relay and after half a million operations all the contact resistances had remained below  $0.5\Omega$ . The contacts of another relay had been lubricated with fully refined paraffin, giving very similar results.

These and other results seemed to justify their possibly premature conjecture concerning contact resistance and lubrication. They fully recognised that the use of contact lubricants might create more problems than it solved and their investigations were, therefore, continuing.

**Mr. Leggett** agreed there was one big difference, he believed, between the contacts used on London Transport and those used by British Railways; and that was that London Transport used graphite whereas British Railways used silver impregnated graphite. There was no doubt that lubricants could give advantages when used on the contacts, but too much was as bad as too little, so how did you control the amount that was put on? It certainly seemed that with pure carbon something was required as an additive. Even if one took silver-to-silver it was unusual to have direct pure silver to pure

silver; 1% only of graphite in one of the contacts would add sufficient lubricant to give a much better life and contact wear, and lower contact resistance. It was very interesting to note Mr. Hobbs's conclusions over contact resistance; he was sure if they averaged 8 ohms and 4 ohms with the relays used by British Railways some dire comment would have been passed before now.

**Mr. Candler** said he had been very interested in Mr. Hobbs' remarks about damp contacts, because that was exactly his experience. They once had a patch of trouble with relays which were perfectly all right in damp weather, and they were all right for a week or so after the weather turned dry, but if it remained dry for a long time, then up went the contact resistance. They found this was due to deliquescent salts drying out on the contact faces and it was one of the reasons why they now insisted on absolute purity in their carbon contacts.

As to lubricants, he was also in favour of lubricants on the contact face, but one had to be extremely careful what was put there, and he would be very chary about putting anything there that was not absolutely inert. Anything with halides in rather put him off, because he always thought of corrosion in connection with chlorides.

They had found that if one operated a relay too fast the life measured in operations was reduced excessively. One latched relay which they tried to test in a hurry at about five times the normal rate, lasted about one-tenth of its normal life, and similar relays tested at the normal rate, which was up or down about every 15 seconds he believed, went on and on and on to about six times normal life. It rather looked as though if one operated the relay too fast one would shake it to bits. He believed some tests also made in the laboratories at Crewe bore out this experience.

He could just add that in the B.R. specification there was a rate laid down of 250 operations per day, = 5.75-minute intervals.

**Mr. A. N. McKillop** said he was neither a user nor a manufacturer, so his remarks should be impartial, and might be of more interest because of that. In

congratulating Mr. Candler and Mr. Leggett on their paper, he was nevertheless a little disappointed that they had not stepped back just a little further and made some general comments or conclusions about the miniature relay. Why was the module chosen in the first place, and was it unsatisfactory? Mr. Pearch said he thought that the miniature relay, or at least the signalling relay in its present form, would go on for a considerable time, but he wondered if, with all the troubles that had been experienced and which had been mentioned by a number of speakers, the miniature relay in its present form really was the best way to have this relay. Had the designers been cramped by the particular dimensions which were settled? Another point was that little mention had been made of the twin relay and it seemed to him that this was a particularly useful device and one wondered why, if it was possible to get two assemblies into a miniature relay case, one should stop there and not go on to get three or four? Why two, and were there any special difficulties that made it advisable to standardise only on the single one?

He also felt rather regretful that the authors had not taken the opportunity of casting some stones at the circuit designers. Did the authors design the relays to suit the circuit, or did the designers adapt the circuit requirements to the characteristics of the relays? In other words, who was it that made the balls and who was it that fired them? And did they find any difficulties; were they frustrated by the requests which were made to them; were there too many different types of relay; and so forth? He would be interested to have the authors' views on this.

The other question that seemed to him to be of some interest was whether the miniature relays should be mounted individually or in groups. In the Continental plan, this group design was tried, but apparently it had been discarded as far as British practice was concerned. It would be interesting to know whether the authors had any views about this and whether, in their opinion, it would be more convenient to have group relays, so that a number of relay movements were mounted in a common case with only one set of plug-in socket connections, instead of individual relays with plug-in socket connections and then group units which

also had plug-in sockets?

**Mr. Candler** said Mr. McKillop had asked, was their module satisfactory? It must be remembered that in 1960 when they began, they rather went out into the blue to fix their module. Their designers said it was feasible but quietly reserved space for future commitments they knew jolly well would appear (and did). It had proved an excellent choice; actually they had just about got everything into it that they had been asked for but they had now reached an absolute limit in some relays.

Various troubles had also been mentioned. Well, there had been various troubles, but one could not get out 18 absolutely new mechanisms or designs in about 5 years without meeting troubles. They were rather forcing the pace.

Mr. McKillop also said that they had not mentioned twin relays, but they were dealing with the design side and the twin relay was just one item in a long list. That was not to say that there were not thousands and thousands of twin relays and it was rather interesting in this instance that the twin relay came first and the circuit men absolutely pounced on it. They usually went step by step; they agreed with the circuiter what he was looking for; he came back and said "look, you've given me 12 contacts, I want 20"; then they said "we'll see what we can do and compromise on 16". They really did get along in a friendly manner, but every now and then they had a nice breakthrough like the twin relay, and everybody was pleased about it.

About grouped relays, there were such things as geographic circuits in which

bunches of miniature relays were mounted on little frames, each one either plugged or fixed in, and then all the connections were wired up and brought down to a second plug base. They were hoping to have introduced one of these that evening, as a demonstration, but they could not get hold of one.

**Mr. Leggett** said he had little more to add to that. Why not more relays in the relay case? It was quite enough getting the two in. Let them not try to cram any more in. He was not saying it couldn't be done; they had, in fact, put three or four Post Office relays inside the miniature relay case. They thought that was quite enough for the time being; if they put more in they would have to reduce the performance specification.

Referring to circuit designers, they brought out a relay design and one said "Ah, just what we want for so-and-so", which then horrified the designer by overworking his relay, so a change of design was made, sometimes for the better.

He thought this would always go on all the time there was progress; if for once everybody was happy and good friends, there was something wrong. All the time one was on edge—designers *versus* equipment, circuit designers *versus* equipment designers—then he thought one would get the best, still being friends but trying to make sure that the other one did not catch you out!

THE PRESIDENT then closed the meeting with a vote of thanks to the authors.